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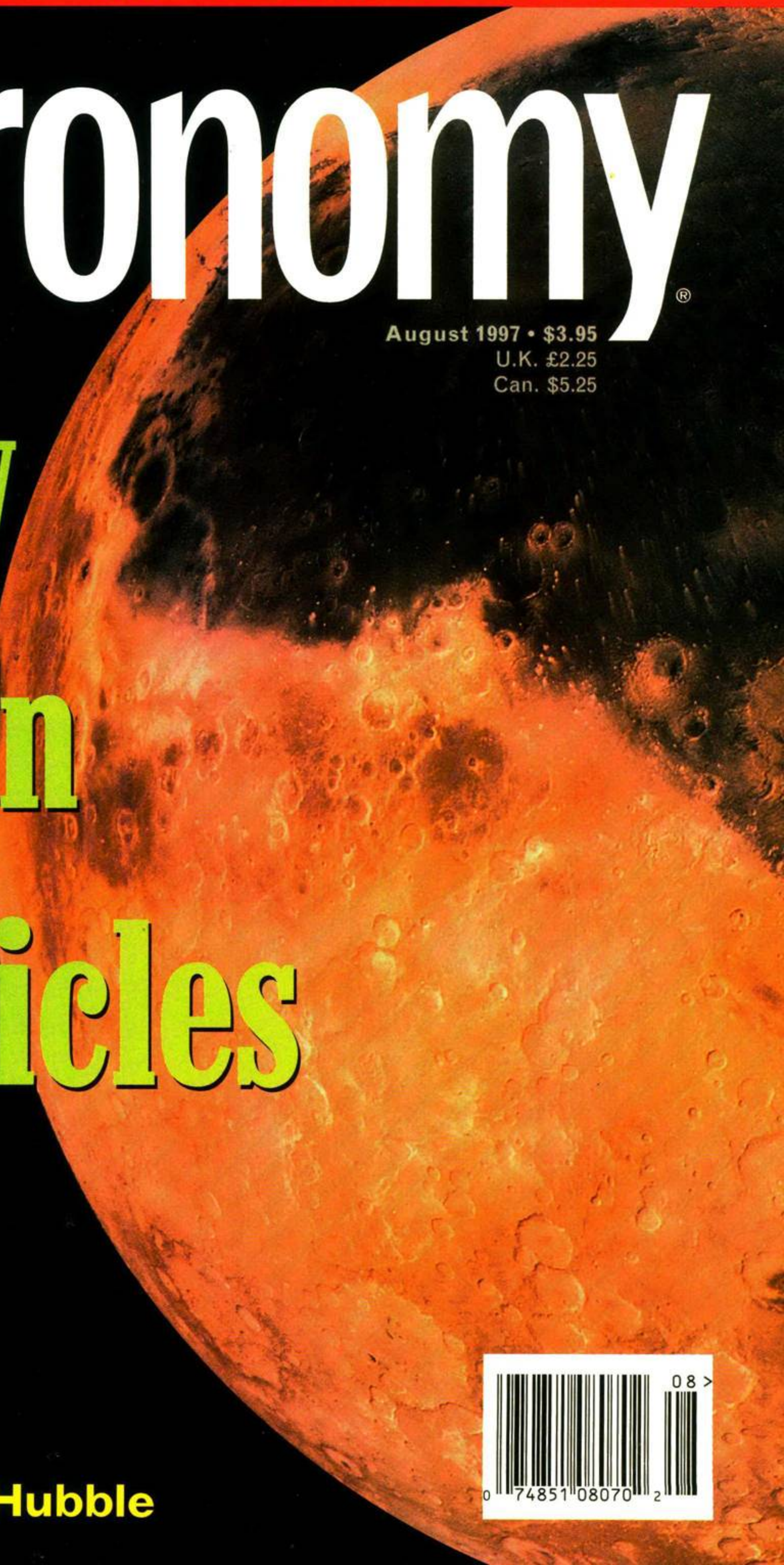

The New

WHERE DO WE

Martian

GO TO FIND

Chronicles

LIFE ON MARS?

Improving our View with a Cosmic Lens

The Man Behind Hubble

LX50

Advanced technology at the most affordable prices *ever.*

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1395.**
10" LX50 Schmidt-Cassegrain	**1695.**
7" LX50 Maksutov-Cassegrain	**1795.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y	**1295.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$495.** + $15 packing and shipping in the 48 states.

MEADE
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COMPUTER-CORRECTOR
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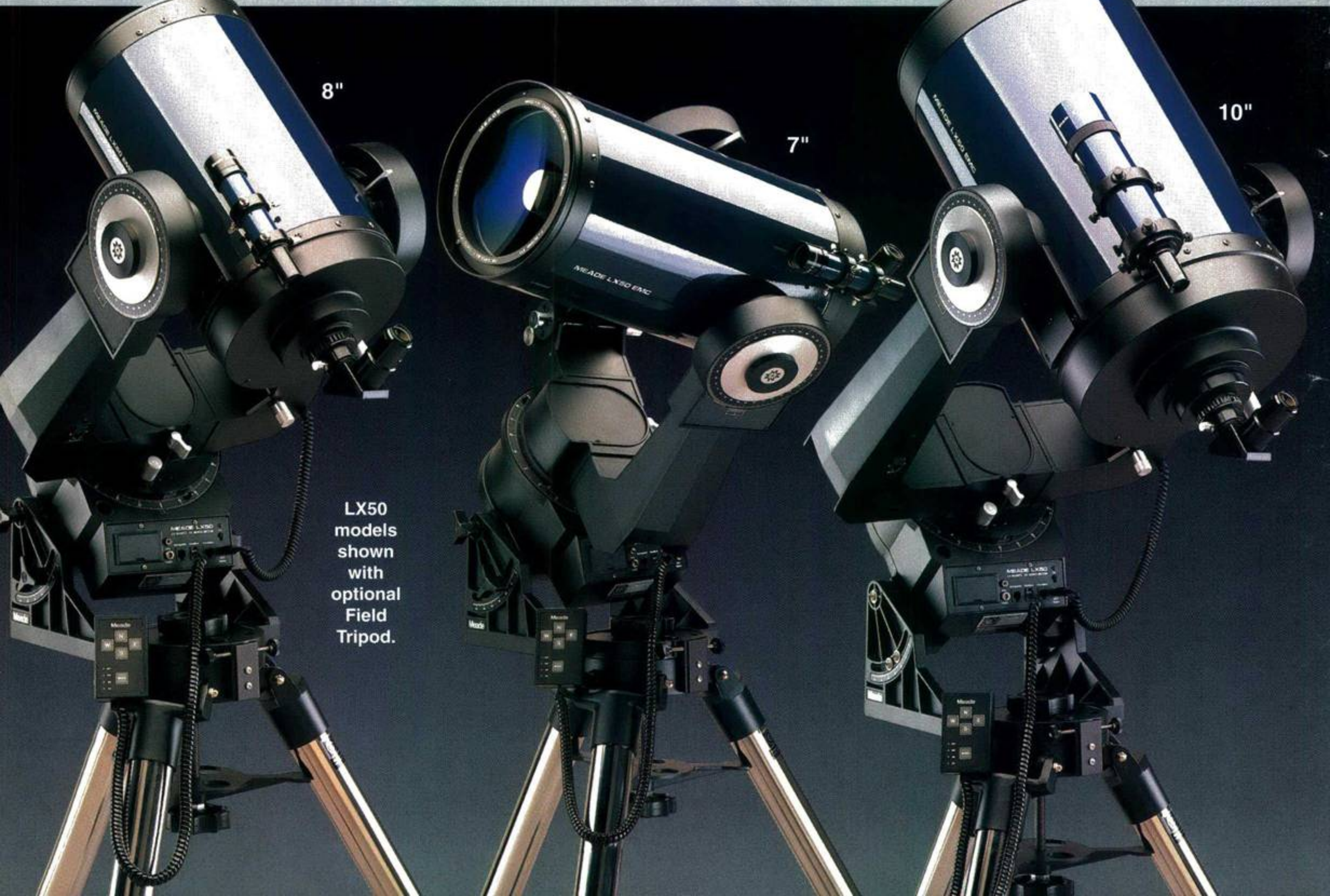
only $495!



LX50 models shown with optional Field Tripod.

The largest-selling serious telescopes in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models *combined*. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, *to a precision of one arc-minute or better.*

8" LX200 Schmidt-Cassegrain	$2795.
10" LX200 Schmidt-Cassegrain	3195.
12" LX200 Schmidt-Cassegrain	4495.
7" LX200 Maksutov-Cassegrain	3295.

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

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COVER PHOTO: U.S. Geological Survey

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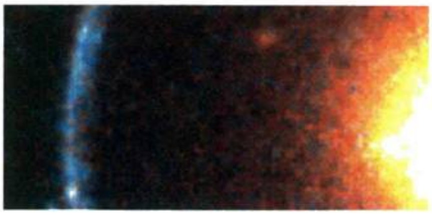

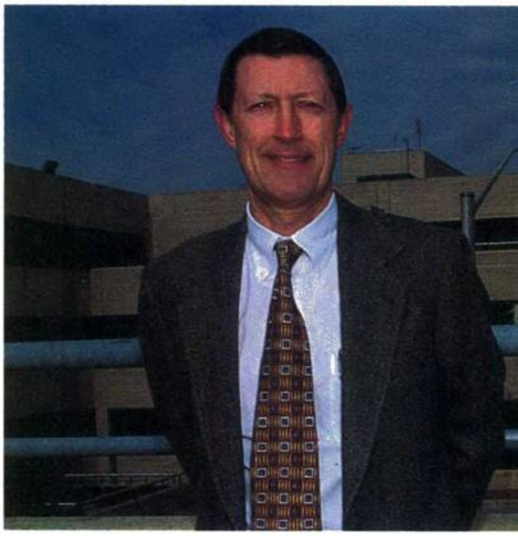

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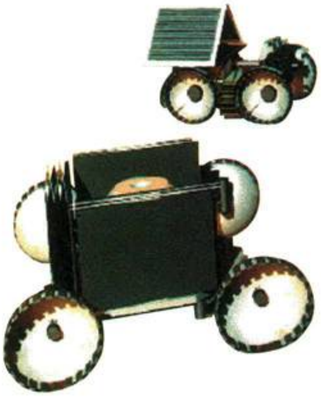

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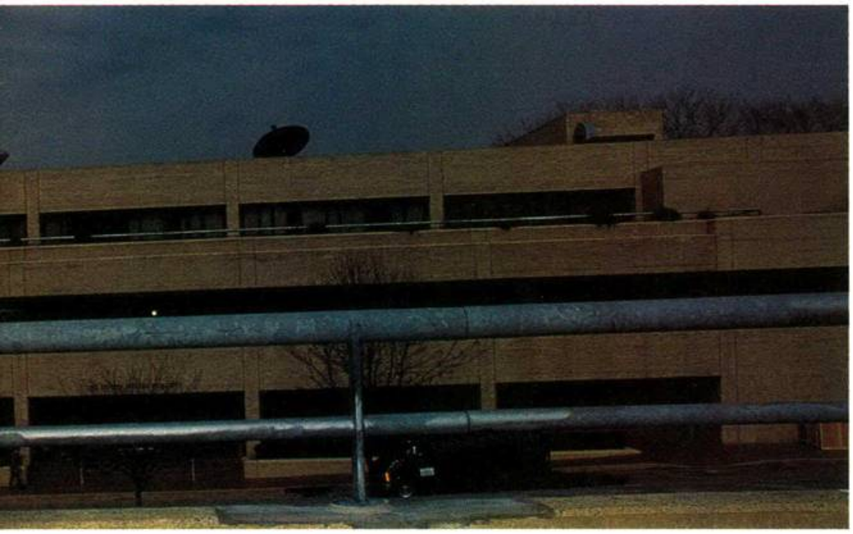

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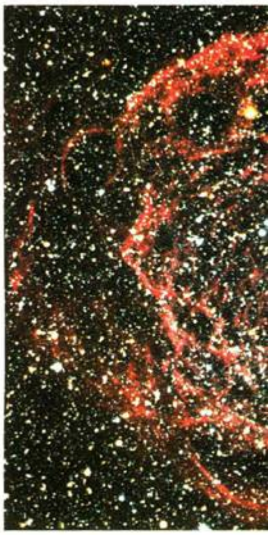

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Anglo-Australian Telescope Board/David Malin

x50 7°30'
8 X 56

BEHIND THE SCENES

BY BONNIE BILYEU GORDON

Going to Mars

The great revival of interest in Mars began last year when a meteorite the size of a yam was linked to life. The rock had lain around Antarctica for about 13,000 years before Roberta Score picked it up on a NASA meteor hunt. Almost immediately everyone recognized that it was very old. Still, it lay around on a laboratory shelf at the Johnson Space Center for another decade before David Mittlefehldt realized it was probably from Mars. Very old and from Mars — that was hot. So other people began to look at it and suspect it held a fossil version of early life.

USGS

Gusev Crater on Mars, probably an ancient dried lake bed, is one pick as best target for searching out remnants of life.

The American public, in fact the international public, has shown about as much excitement over the rock as it has shown over anything astronomical since the last time humans went to the moon — in 1972, 25 years ago in December. And NASA has embraced Mars "with all the ardor a financially strapped government agency can muster."

To make a true case for a biological Mars, we need better samples and we've either got to go get the samples ourselves or send a robot to do it for us. In "Looking for Life on Mars" on page 38, NASA planetary scientist Christopher McKay describes some good potential locations for finding the remains of life on the Red Planet. To locate the traces of life we should start looking for places where water once flowed, he says. And we need to search out the spots where critters could most easily transform to fossils as well. McKay will fine-tune your martian fantasies with a tour of lake beds, hydrothermal springs, ice banks, and craters.

While some scientists are plotting the best landing sights for robots — or humans — others are busily hatching a grand scheme to cut the cost of a first trip to Mars and get people there by 2011. Some of the NASA thinkers are aiming not only to get humans to Mars but also to open permanent outposts there in the same year. Impossible, you think? David Portree might convince you otherwise in his delight-filled "The New Martian Chronicles" on page 32.

Bon Voyage.

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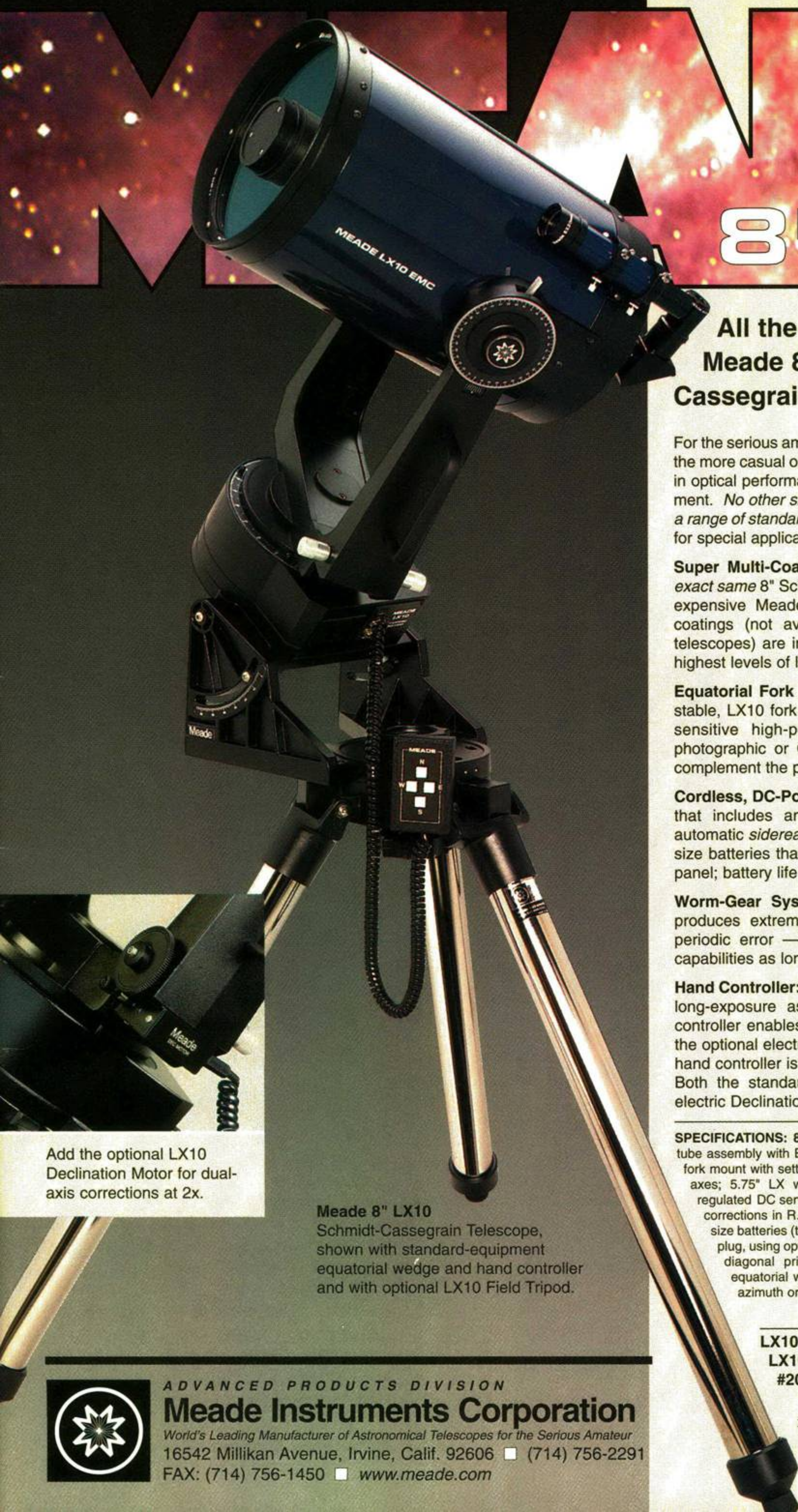
MEADE 8" LX10



Add the optional LX10 Declination Motor for dual-axis corrections at 2x.

Meade 8" LX10
Schmidt-Cassegrain Telescope, shown with standard-equipment equatorial wedge and hand controller and with optional LX10 Field Tripod.

All the optical performance of Meade 8" LX50 and LX200 Schmidt Cassegrains...for only *$995!*

For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *No other similarly-priced 8" Schmidt-Cassegrain offers such a range of standard features* — or such a range of important options for special applications. *Standard-equipment includes:*

Super Multi-Coated Optical System: The LX10 includes the *exact same* 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. Super multi-coatings (not available even as an *option* on competing 8" telescopes) are included with every LX10 optical system, for the highest levels of light transmission and image contrast.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. Ball bearings on the polar axis complement the precise action of the internal worm gear system.

Cordless, DC-Powered Electronic Motor Drive: A drive system that includes an electronically-regulated DC servo motor for automatic *sidereal-rate* tracking. The drive is powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4- pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions.
$995. (+ $65 packing & shipping in the 48 states)

LX10 Field Tripod	**195.**
LX10 Electric Declination Motor System	**85.**
#2014 Magellan I Telescope Computer System for LX10, with 12,218-object database	**375.**

The 94-page Meade 1997 General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers. Prices shown are suggested U.S. mail-order prices.

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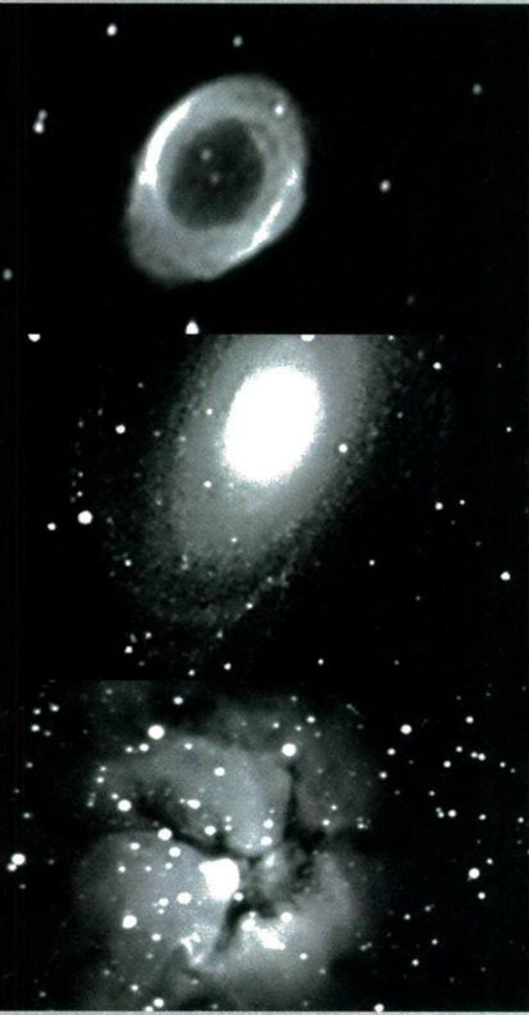
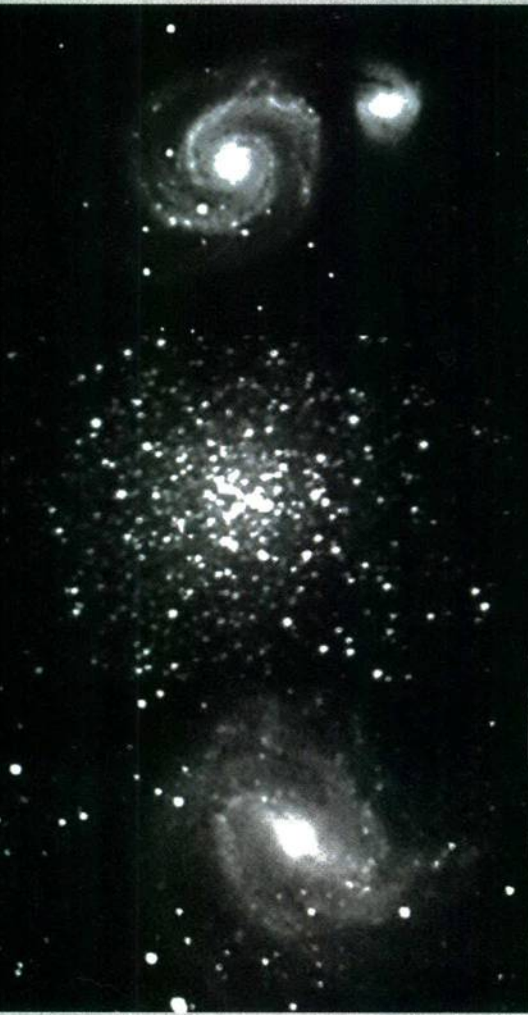
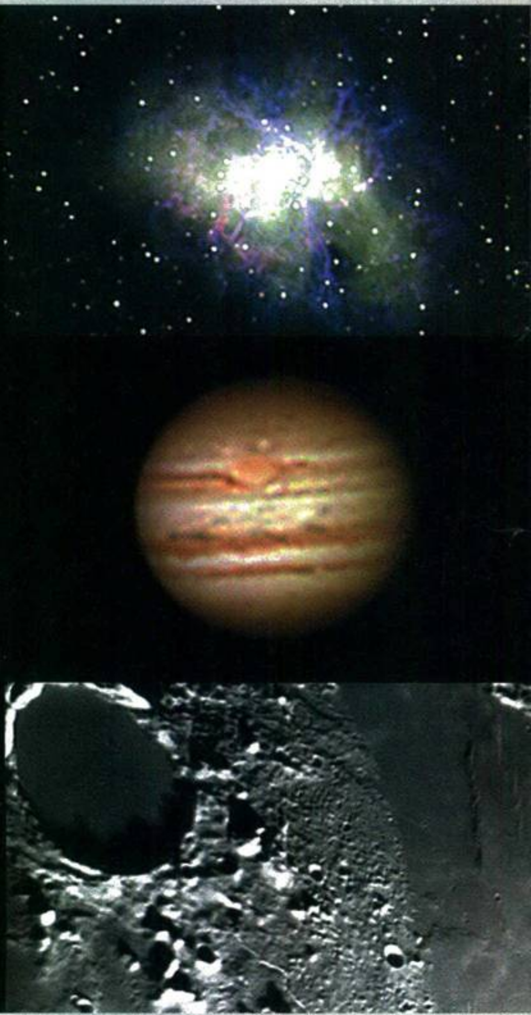
Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only **$495** the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets, or, in 2 or 3 minutes, of thousands of deep-space objects. At **$695** the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-$1000. At **$1695** the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. ***For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 94-page Meade 1997 General Catalog.***



Pictor 208XT images *(top to bottom):* Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.



Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.



Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

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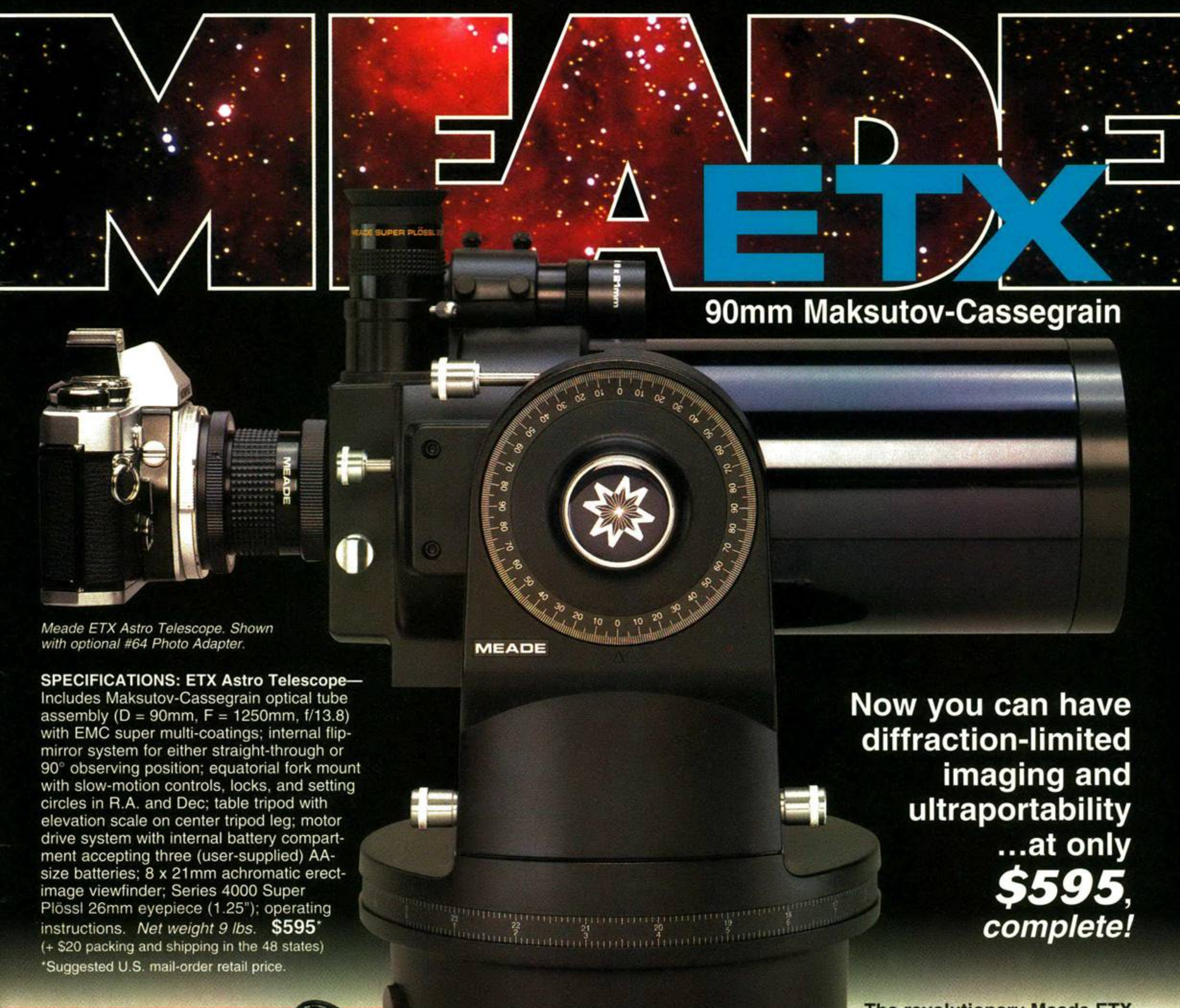
MEADE ETX

90mm Maksutov-Cassegrain



Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. *Net weight 9 lbs.* **$595***
(+ $20 packing and shipping in the 48 states)
*Suggested U.S. mail-order retail price.

Now you can have diffraction-limited imaging and ultraportability ...at only *$595*, *complete!*

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds,* just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.

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MEADE STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of *standard-equipment* features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

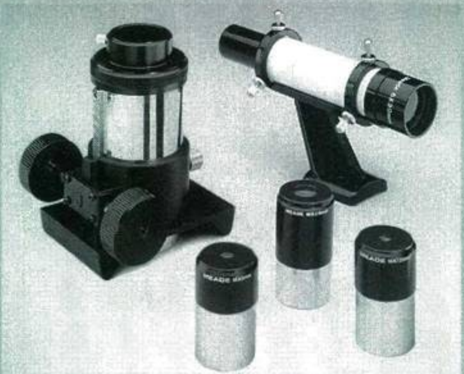
5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials *(right)*, tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! *Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world.* Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$39; 8"—$49; 10"—$69; 12.5"—$79; 16"—$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only $49.95!



Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the standard-equipment focuser, viewfinder, and eyepiece, ***for a total of only $49.95 additional:***

1 - **Meade #77 2" Giant Rack-and-Pinion Focuser,** with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. *(reg. $59.95)*

1 - **Meade #637 6 x 30mm Achromatic Viewfinder,** with wide 7° field; 2-ring metal bracket. *(reg. $49.95)*

3 - **Meade MA9mm, 12mm, and 25mm** multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. *(reg. $37.95 each)*

Purchased separately, the Deluxe Accessory Package sells for $223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or *any* object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

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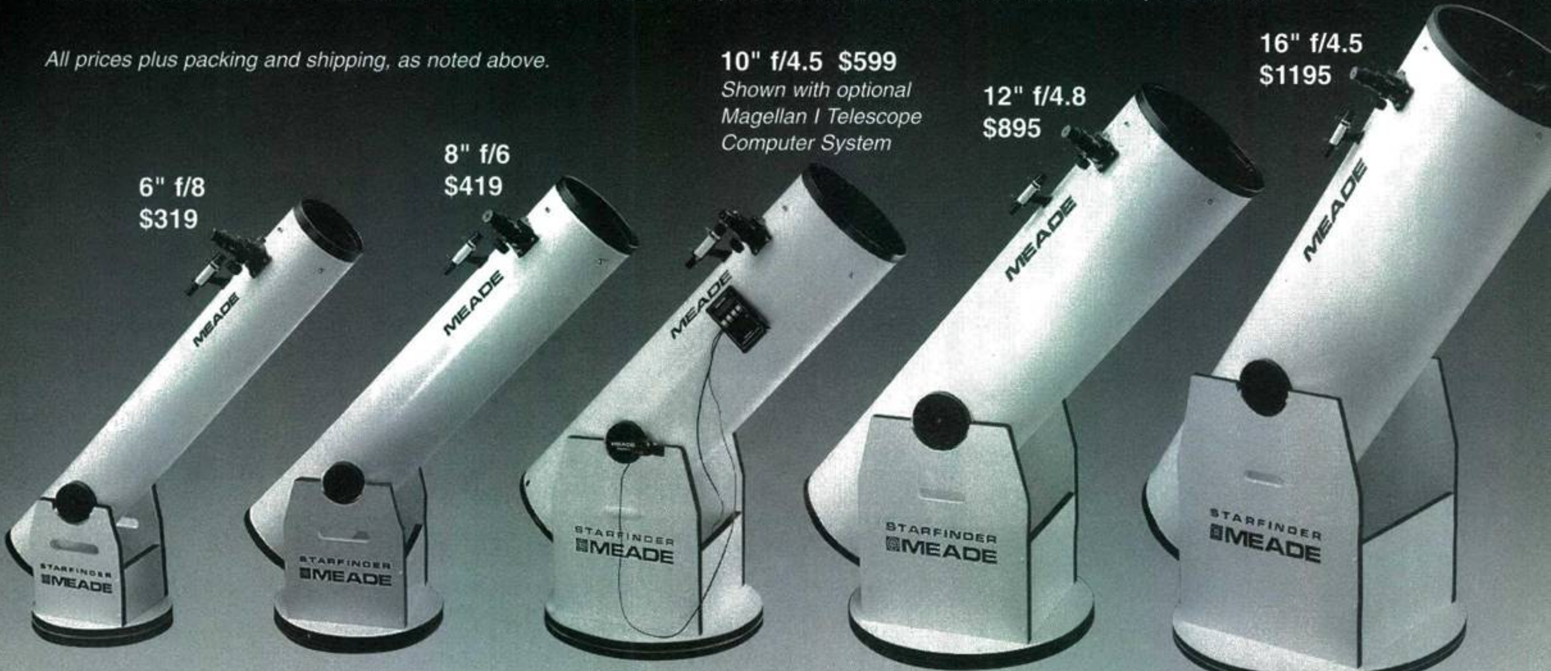
MAGELLAN I
TELESCOPE COMPUTER SYSTEM

Magellan I is supplied *complete* with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.

#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" . . . . $295.
Packing & shipping in the 48 states—$15.

STARFINDER DOBSONIAN TELESCOPES ***Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.***

All prices plus packing and shipping, as noted above.



6" f/8
$319

8" f/6
$419

10" f/4.5 $599
Shown with optional Magellan I Telescope Computer System

12" f/4.8
$895

16" f/4.5
$1195

MEADE STARFINDER EQUATORIALS

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, ***for a total of $29.95!*** *Purchased separately, the 2 eyepieces sell for $75.90.*

The fullest exposition of Meade astronomical telescopes, CCD imagers, and telescope accessories is contained in the 94-page Meade 1997 General Catalog.

Write, call, or fax Meade Instruments for your free copy!

To Order: Contact your authorized Meade Advanced Products Dealer. Prices shown are suggested U.S.A. mail-order retail prices.

AUTHORIZED U.S. MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders & Information: 818-505-8424.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; Illinois: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—$65; 8"—$75; 10"—$90; 16"—$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

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TELESCOPE COMPUTER SYSTEM

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians *(see facing page).*

#2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" . . . . $295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" . . . . 295.

MEADE
MAGELLAN II
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Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, *plus* a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.

#2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" . . 495.
#2019: for (DC-powered) Starfinder Equatorial 16". . . . . 595.

Packing & shipping in the 48 states: Magellan I–$15, Magellan II–$20.

ADVANCED PRODUCTS DIVISION

Meade Instruments Corporation

World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur
16542 Millikan Avenue, Irvine, Calif. 92606 ☐ (714) 756-2291
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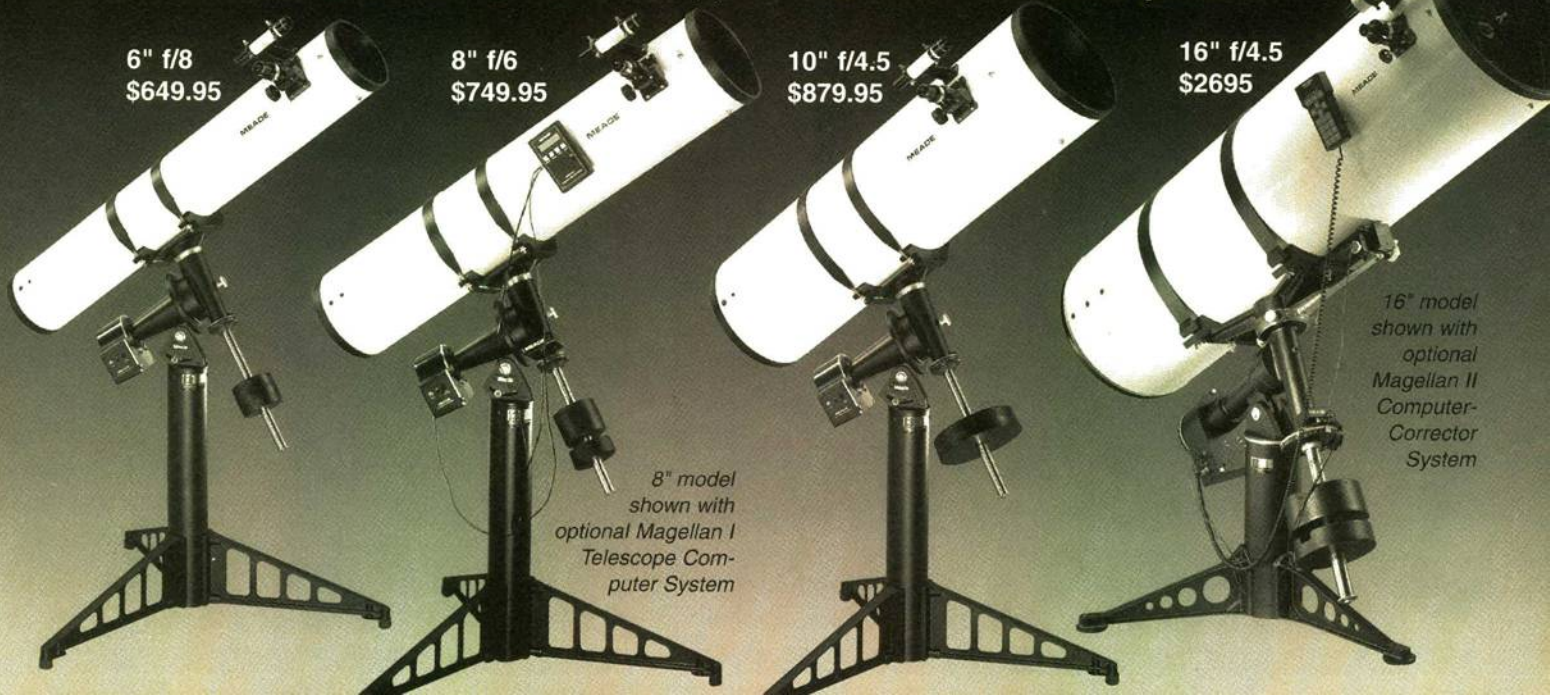
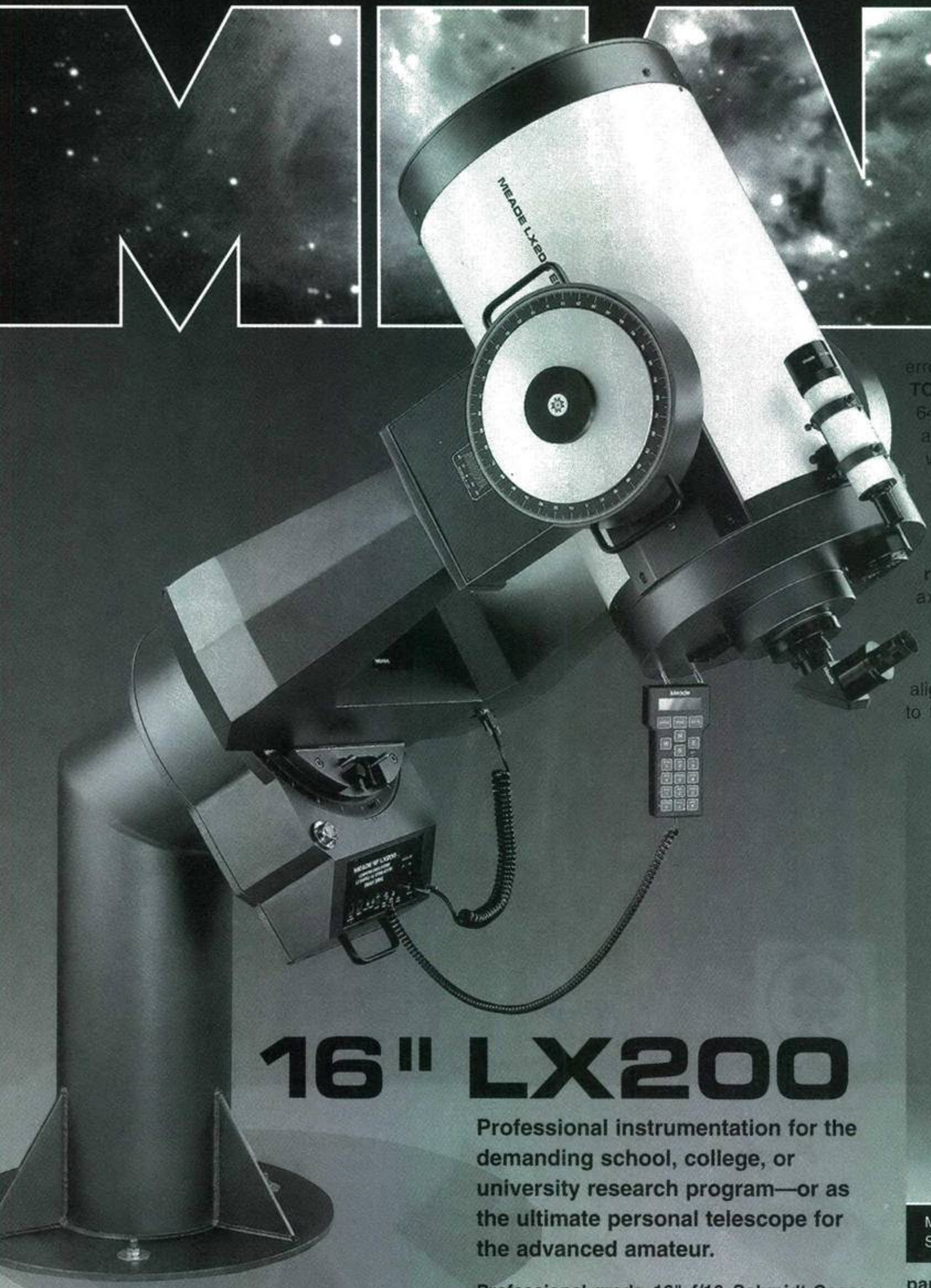
STARFINDER EQUATORIAL TELESCOPES ***Shown with standard-equipment 6 x 30mm or 8 x 50mm viewfinder and 2" giant focuser.***



8" model shown with optional Magellan I Telescope Computer System

16" model shown with optional Magellan II Computer-Corrector System



16" LX200

Professional instrumentation for the demanding school, college, or university research program—or as the ultimate personal telescope for the advanced amateur.

Write, call, or fax Meade Instruments for your free copy of the 94-page Meade 1997 General Catalog, with complete information on more than 40 Meade telescope models.

Professional-grade 16" f/10 Schmidt-Cassegrain optical system meets or exceeds advanced requirements; includes BK7 correcting plate with EMC super multi-coatings for high UV transmission. ■ **Massive one-piece fork mount** permits substantial auxiliary equipment to be piggybacked with rock-solid stability. ■ **Large 11" worm gears** on both axes, with factory-programmed Smart Drive™; periodic error less than 5 arc seconds. ■ **Automatic GO TO capability** to any object in the onboard 64,359-object database or to any input R.A. and Dec. ■ **High-Precision Pointing™** to within one arc-minute in the GO TO mode. ■ **DC servo drive systems** with integrated encoders and planetary gearboxes; encoder resolution: 0.13 arc secs. ■ **Six pushbutton-controlled drive-speed rates,** from photo-guide to fast-slew on both axes, simultaneously. ■ **Microprocessor controlled sidereal-rate tracking** in AZ or EQ modes with quartz accuracy. ■ **Home-Pulse Acquisition** permitting remote alignment and operation through a modem link to the telescope's RS-232 interface. ■ **Control panel connectors** for optional systems including CCD autoguiders and imagers, electric focuser, and the Meade **#1222 Field De-rotater** for long-exposure astrophotography in the AZ mode. ■ Available with **supergiant transportable field tripod** (2-person field set-up in less than 10 minutes); **permanent altazimuth pier** (permitting the entire instrument to be housed in a 2-meter dome); or **permanent equatorial pier** (in cases where piggybacked astrocameras do not permit field de-rotation).

Meade 16" LX200 Schmidt-Cassegrain, with Supergiant Transportable Field Tripod.

The Meade 16" LX200 is in continuous production at the Meade Irvine, Calif. factory. **Delivery time:** 4 to 12 weeks. **Price:** $14,950, complete with supergiant field tripod, plus $385 packing and shipping in the 48 states; prices slightly higher with permanent altazimuth or equatorial pier.

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World's Leading Manufacturer of Astronomical Telescopes for the Serious Amateur

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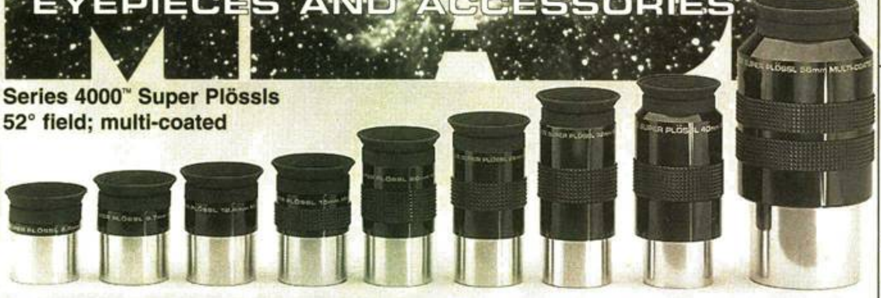
MEADE

EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössls 52° field; multi-coated



Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössls (SP; 4-elements; 1.25"; 52°):

6.4, 9.7, 12.4, 15, 20, 26mm	each:	**$79.95** (3.45)
32mm (52°); **40mm** (44°)	each:	**99.95** (3.79)
56mm (52°; 2")		**199.95** (5.48)

Series 4000™ Ultra Wide Angle 84° field; multi-coated

The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (3.94); **6.7mm: 199.95** (3.94); **8.8mm** (1.25"/2"): **239.95** (5.87); **14mm** (1.25"/2"): **299.95** (6.28)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

$129.95 (3.60)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

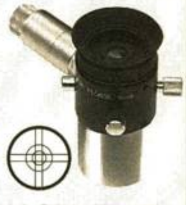
#929 or **#930**, each: **$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

$42.95 (3.45)

World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

$149.95 (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

$129.95 (3.45)

Series 4000 Photo-Visual Color Filters (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue each **$14.95** (2.29)

Set #1–4 filters: #12, #23A, #58, #80A	**49.95** (2.98)
Set #2–4 filters: #11, #25A, #47, #82A	**49.95** (2.98)
Set #3–4 filters: #8, #21, #38A, #56	**49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **$16.95** (2.29)

#905 Variable Polarizer (1.25")

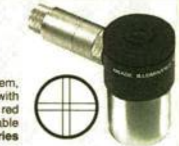
For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. **$49.95** (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" **Batteries included.** **$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": **$27.95**; 1.25": **$29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

$79.95 (4.27)

Series 4000™ Super Wide Angle 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm** (2"): **239.95** (5.87); **40mm** (2"): **299.95** (6.28)

Series 3000™ Plössls 50° field; multi-coated

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

#911B
#910B
#908B
#911N
#910N
#908N

Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of-light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B–Threads into 1.25" eyepieces, 26mm dia.	**79.95** (3.45)
#910B–Threads into 2" eyepieces, 44mm dia.	**119.95** (3.85)
#911B–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**99.95** (3.94)
#908N–Threads into 1.25" eyepieces, 26mm dia.	**89.95** (3.45)
#910N–Threads into 2" eyepieces, 44mm dia.	**129.95** (3.85)
#911N–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia.	**119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, **multi-coated.** Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

HOW TO ORDER

■ Prices shown are suggested U.S.A. mail-order retail prices and do not include any applicable sales taxes.

■ Suggested shipping and handling charges to the 48 states by U.P.S. or U.S. Mail shown in ( ) next to each price.

■ Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

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Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

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LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

RIVERS CAMERA, Dover, NH.
Orders: 800-245-7963; Info.: 603-742-4888.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders & Info.: 800-621-2248; IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

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TALKING BACK FROM OUR READERS

Going Once, Going Twice, Sold!

With the advent of bigger and better entertainment toys, planetaria are finding it increasingly difficult to attract audiences and pay their own way. In some cases, razzle-dazzle laser shows have increased attendance, but most planetaria face an uncertain future.

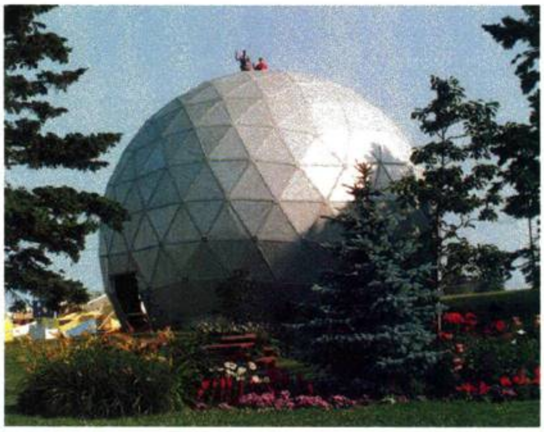
The University of Prince Edward Island Planetarium in Canada was one. In addition to showing no profit since its inception, its projector sustained $60,000 worth of flood damage, resulting in the closing of the facility seven years ago. Though many public initiatives were organized to save it, each faltered. Finally, a public tender was announced, leading most to anticipate that the local scrap merchant would be the lucky bidder and a wonderful institution would be lost.

Much to everyone's surprise, we were the successful bidders. Actually, we were the only bidders, and $1,200 bought the planetarium. When first built, it cost $250,000 and replacement value today would approach $1 million (all Canadian dollar amounts). The planetarium is spectacular, housed inside a huge, 50-foot aluminum geodesic dome. An inner theater boasts a 30-foot dome screen and an A3P star projector.

A former greenhouse business owner and a retired flying instructor in the Canadian Air Force, my wife and I decided years ago to get involved in something to interest kids in science. We built Atlantic Canada's first science center (in the cargo bay of a full-size space shuttle replica). The planetarium seemed the perfect addition to our Great Island Science & Adventure Park.

As spare time and money became available, we began the process of disassembling and rebuilding. Crises seemed to lurk at every turn. Like all geodesic domes, ours leaked. And at one point during the rebuilding stage, the partially completed dome was blown from its supports by strong winds. Patiently and systematically, we confronted each hurdle we met. After the dome was complete, the inner theater was a snap.

In 1996 we were finally able to put on a few live shows. The public appreciation was enough to make the five-year saga worthwhile. Now, only the repair of the star projector remains. We are looking for spare parts, so if you have any or know of any recently closed planetaria, please contact us at P.O. Box 430, Kensington PE Canada C0B 1M0 or by e-mail, scifun@atcon.com.
– Bart and Patty Bourne, Kensington, Prince Edward Island, Canada


Bart and Patty Bourne

The Bournes wave from atop the planetarium they saved.

Science by Mail

I write to let other readers know about a terrific program called Science-By-Mail, run by the Boston Museum of Science. The program provides fourth-through ninth-grade students with hands-on activities that let them explore scientific concepts rather than just read about them in textbooks. A key component of the program is the personal involvement of a scientist "pen-pal" with each group of students. This is the first year I have been involved, and I have enjoyed the

Astronomy.

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ADVERTISING SALES MANAGER
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ADVERTISING SALES REPRESENTATIVE
Colby Waller cwaller@astronomy.com

AD SERVICES REPRESENTATIVE
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chance to interact with the children and to take part in showing how exciting science can be. Additionally, I have helped break down stereotypes they may have had about who can choose a career in science and have encouraged girls and minorities to try their hands at it. I urge others to take advantage of this opportunity to help educate our children. – *Kathleen Johnson, Kennedy Space Center, Florida*

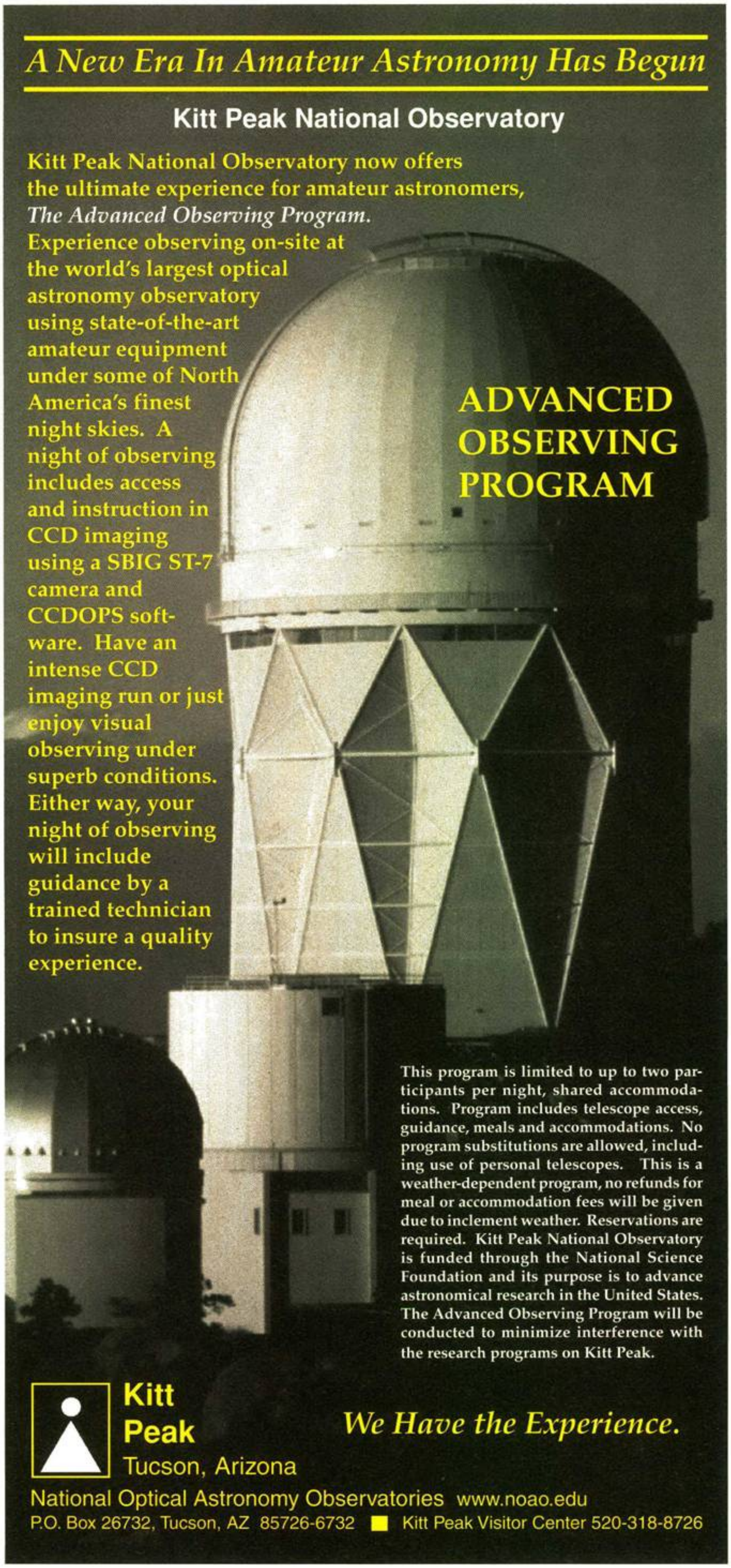
***Astronomy's* New Face**

As I read my June issue of *Astronomy*, I came across the "Behind the Scenes" article entitled "*Astronomy*'s New Face." Your readers might like to know how much the universe has changed since I went to school. (I'm now retired.) First, *Astronomy* didn't exist. No one knew of black holes, neutron stars, solar wind, or the Oort Cloud. Andromeda was considered to be only half as far away as it is now (and therefore only half as big). The sun was considered to be powered by something having to do with Einstein's theory of relativity and Mercury reportedly faced it at all times. Venus was a steaming jungle, Earth had unmoving continents, and Mars had canals and primitive plant life. Jupiter had a big Red Spot, thought to be atmospheric circulation around a floating island. It had 12 moons, but eight were designated by nothing more than a number. Saturn was known as the only planet with rings. Pluto was considered to be slightly larger than Earth. Things do change! – *Webb Masten, Shelby, North Carolina*

Feedback from Down Under

How wonderful to read an article and know most of the objects it describes by sight! I refer to Richard Jakiel's great review of globular clusters seen from the south (May 1997). Though many articles contain enough material to keep astronomers from Down Under interested, it was splendid to have something specifically for us.

I must, however, take exception to the more than colorful imagery in some other articles. To characterize Herschel 36 as "engaging in matricide, killing the nebula from which it was born" ("At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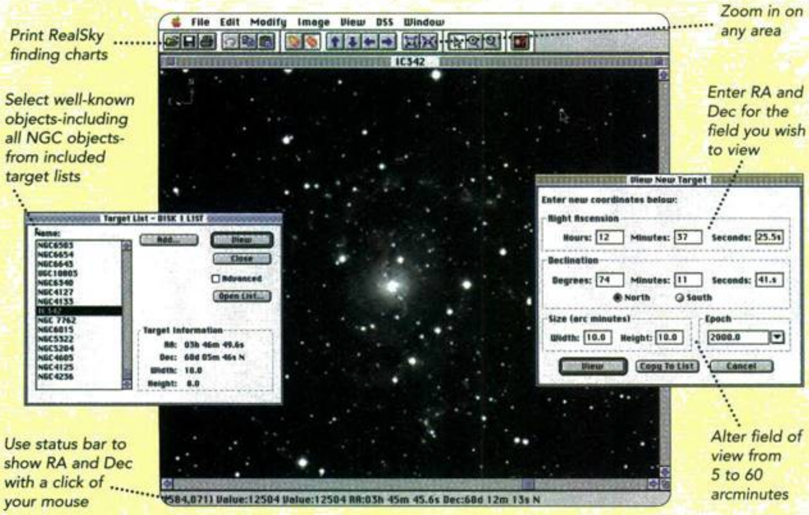
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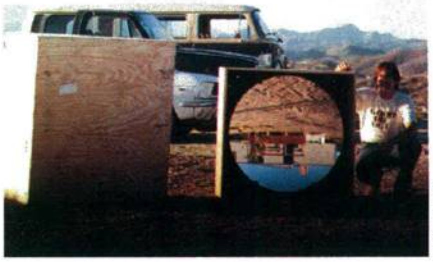
the Heart of the Lagoon," May 1997) is really more than I can bear. To "popularize" science through anthropomorphism, ascribing usually the most twisted of human actions to the natural world, is meaningless sensationalism. The goal, which is surely to seek parallels between nature and humankind, is paradoxically undermined by the effect, which is to "naturalize" abhorrent and abnormal human behavior. Let's just stick to the science! – *Marilyn Head, Wellington, New Zealand*



Richard Clift

Richard Clift seeks information about his "mystery mirror" from other readers.

Mystery Mirror

On a trip to Austin, Texas, I found a 36-inch observatory-grade Newtonian reflector with a 2.9-inch sagitta and a 37-inch focal length. I have searched in vain for books on mirrors of this type, hoping to obtain information on how to build a satisfactory system. I did find an old slip of paper with "mirror #4" on it taped inside, but the people I purchased the mirror from knew nothing about its history. Maybe there's an *Astronomy* reader out there somewhere who could help me?
– *Richard Clift, Claypool, Arizona*

Correction

The Gems of Light website in June's New Products column should have read http://GKB3.GIM.NET/GEMS. ◼

Astronomy *invites you to talk back. Send letters to* Astronomy *Talking Back, P.O. Box 1612, Waukesha, WI 53187; e-mail to talking@astronomy.com. Letters may be edited for space or clarity.*

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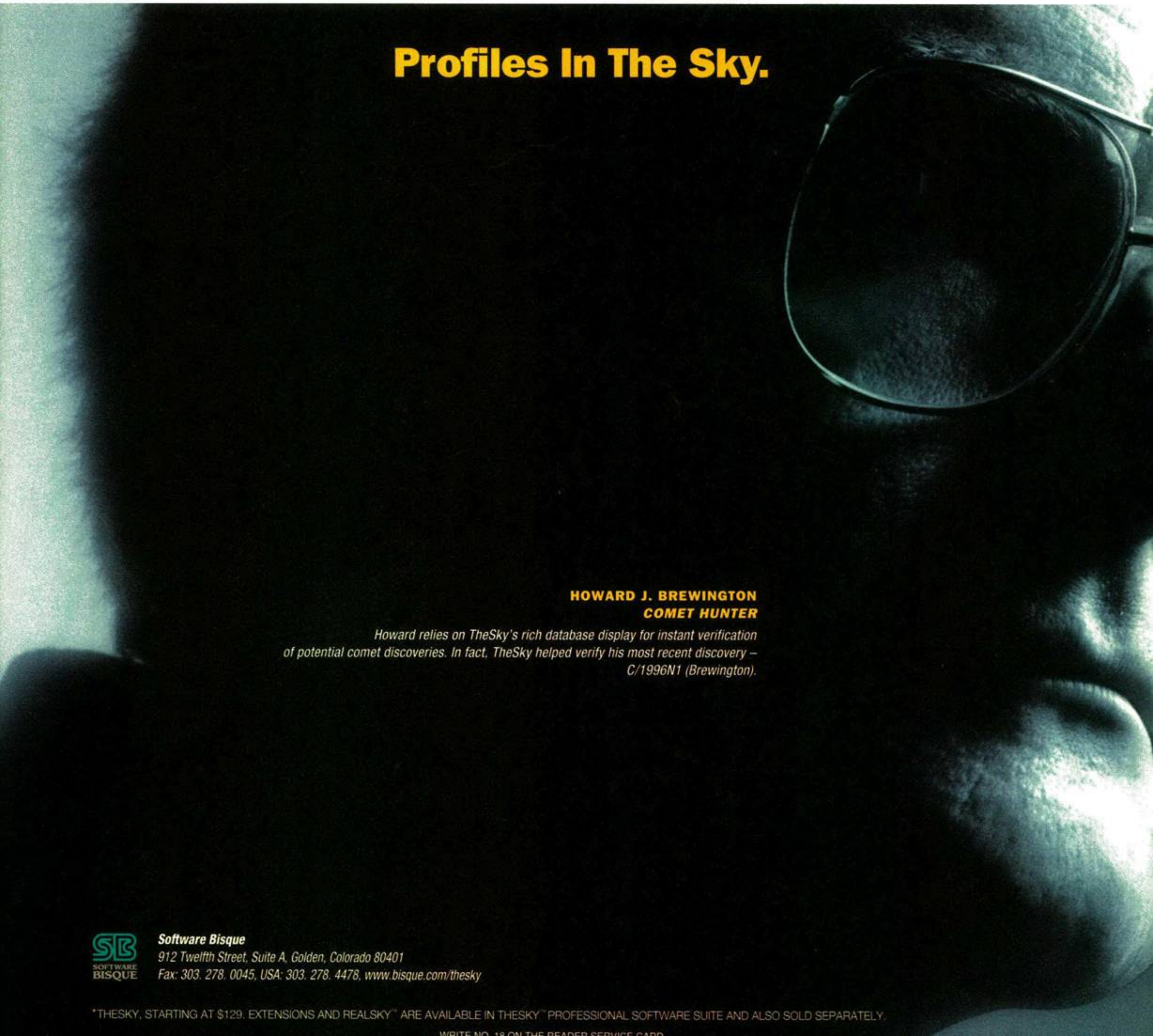

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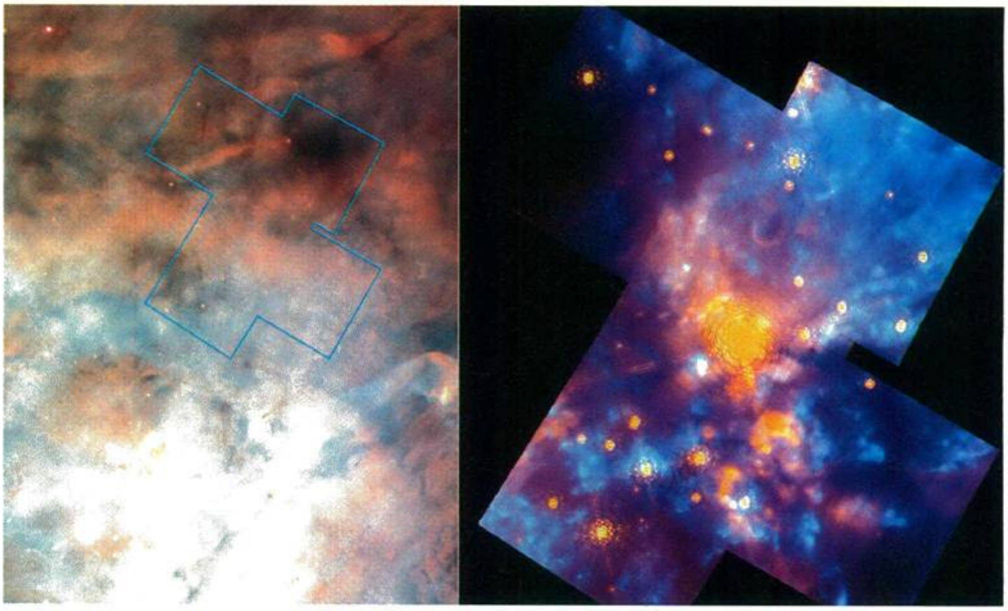
New camera and spectrograph performing well

▶ The wait is over. Three months after the February servicing mission that saw a crew of seven astronauts replace or refurbish several instruments, NASA released the first scientific findings from the updated observatory. And the results are truly spectacular.

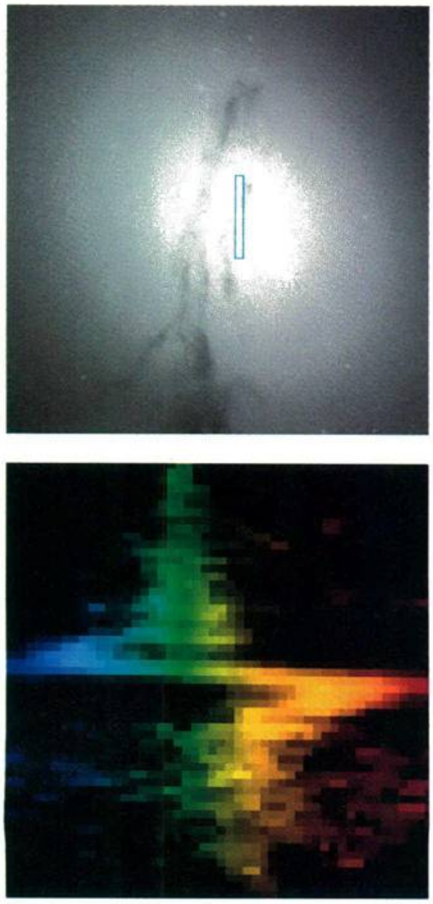
The Near Infrared Camera and Multi-Object Spectrometer (NICMOS) penetrated the dusty shroud that envelops the molecular cloud OMC-1 in the Orion Nebula. NICMOS revealed a surprising array of structures in the giant stellar nursery, including clumps, bubbles, and knots. Perhaps the most remarkable features are "bullets" of molecular hydrogen moving up to one million miles per hour. When these bullets collide with slower-moving material, they create bow shocks like those from a speedboat racing across water.

The Space Telescope Imaging Spectrograph, or STIS, has discovered an enormous black hole lurking at the center of the galaxy M84 in Virgo. STIS recorded a sharp rise in the velocity of gas near M84's center, peaking at a speed of 880,000 miles per hour. Only a black hole of 300 million solar masses or more could cause the velocity to skyrocket like this.

NASA reports that all the upgrades are doing well except for NICMOS, where one of its three cameras remains out of focus. The solid nitrogen used to keep the sensitive infrared detector cool expanded more than predicted after Hubble's deployment, causing its container to contact another part of the instrument and push the camera out of focus. Project officials are encouraged, however, because the camera has since moved about one-third of the way back toward its internal focus range.



S. Stolovy (University of Arizona) and NASA



NICMOS lifted the dusty veil of a giant molecular cloud in the Orion Nebula, discovering knots, bubbles, clumps, and "bullets" (above, right). The rings and spikes seen around the brighter stars match those expected, indicating that the instrument is performing almost perfectly. (The same patterns exist in WFPC2 images, but show up more clearly in the infrared.) STIS examined the motion of gas in the center of the galaxy M84 (left), showing that the gas rotates at speeds up to 880,000 miles per hour, presumably circling a 300-*million-solar-mass* black hole.

G. Bower (NOAO) and NASA

SWIRLING CONTROVERSY

What's Up in Space?

New finding hints that universe may have an axis

▶ Astronomers frequently remind us that there's no up or down in space. According

(see "What's Up?" p. 22)

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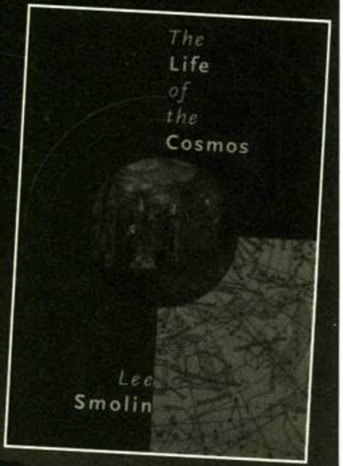

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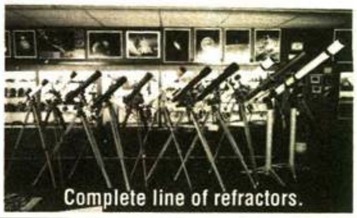

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COMET UPDATE

An Unexpected Tail for Hale-Bopp

► Although Comet Hale-Bopp won't go down as the brightest comet of the century, few backyard observers have complained about the show it put on. But the comet was more than a pretty spectacle. Astronomers, afforded nearly two years' notice about the comet's return, were ready to examine Hale-Bopp in great detail. And their observations helped uncover some startling facts.

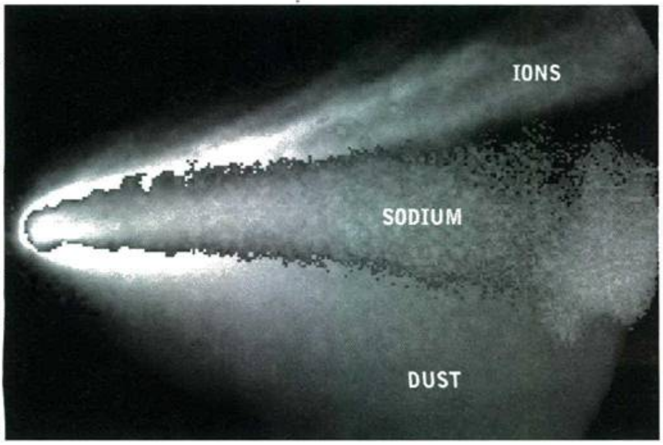
Perhaps the most stunning result was the discovery of a third kind of comet tail — a tail composed of neutral sodium atoms. Although sodium atoms have been seen near the center of other comets, this is the first time that a tail composed of these atoms has been detected. When discovered in mid-April, the tail stretched 6°, corresponding to a length of about 30 million miles.

Don Pollacco of the Isaac Newton Group found the tail on images taken with a wide-field CCD camera on La Palma in the Canary Islands. He shot the images through a narrow filter that isolates the emission from sodium atoms. To his and other astronomers' surprise, the sodium covered an enormous region in and around the comet and stretched back into the region of the tails.

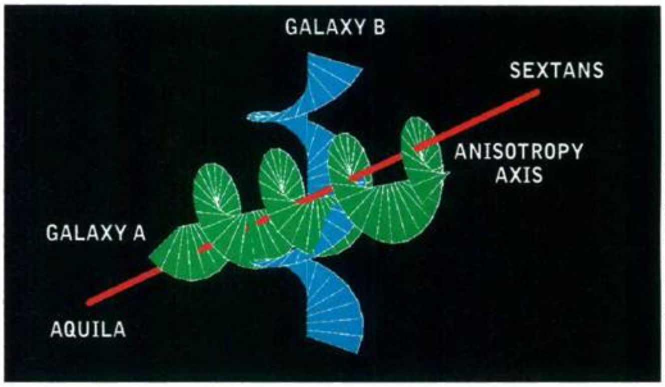
Astronomers have long known about the dust and ion tails of comets. As a comet approaches the sun, the heat causes the ices that make up the comet's "dirty-snowball" nucleus to sublimate, or turn directly from ice into gas, releasing tons of dust and gas.

(see "Hale-Bopp," p. 24)

A newly discovered tail of neutral sodium atoms makes Hale-Bopp the first comet known with three tails. (The sodium emission has been enhanced to make it easier to see.)



J. Wilson, J. Baumgardner, and M. Mendillo (Boston University)



Borge Nodland (University of Rochester)

Does the universe have a twist? If new research is confirmed, the polarization of radio waves rotates a complete turn every one billion light-years along an axis running from Sextans to Aquila.

(What's Up?)

to the laws of physics, as expressed in Einstein's theories of relativity, the universe should be pretty much the same in every direction. But two physicists have published a controversial paper that questions this long-cherished notion.

They claim that the universe might have a "preferred axis," an orientation betrayed in the polarization pattern of radio waves traveling across vast distances of intergalactic space. The axis, if it exists, runs from the direction of the constellation Sextans toward Aquila. "The shocking thing about our result is that there seems to be an absolute axis, a kind of cosmological north star that orients the universe. We don't really know yet what this axis represents," says John Ralston of the University of Kansas, who copublished the paper in the April 21, 1997, *Physical Review Letters* with Borge Nodland of the University of Rochester.

Nodland and Ralston didn't make any observations themselves. Instead, they analyzed published observations of 160 distant galaxies made by radio astronomers during the 1970s and 1980s. Their analysis showed that the polarization of radio waves rotates in a corkscrew-like fashion as the waves traverse space. "It's an unbelievably small effect," says Ralston. "It takes about a billion light-years for the polarization plane to twist once." The discovery could mean that light travels at two slightly different speeds depending on the direction of movement, or it could mean that the Big Bang spawned two universes, each with an opposite "twist."

Nodland and Ralston's paper has been greeted with a sea of skepticism. Critics charge that the two were using old data, and data not originally intended to study this type of effect. Some radio astronomers also say that Nodland and Ralston's analysis is based on too simplistic a model of how galaxies emit radio waves. Ralston responds that he and Nodland used the best available processed data and that they addressed most of these criticisms in their paper. He adds, "Anything as new as this is going to be controversial. This is all part of the chaotic business of science. We published our

(see "What's Up?" p. 24)

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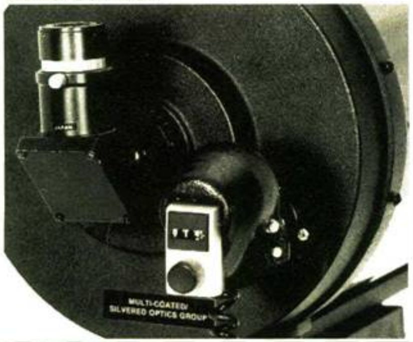

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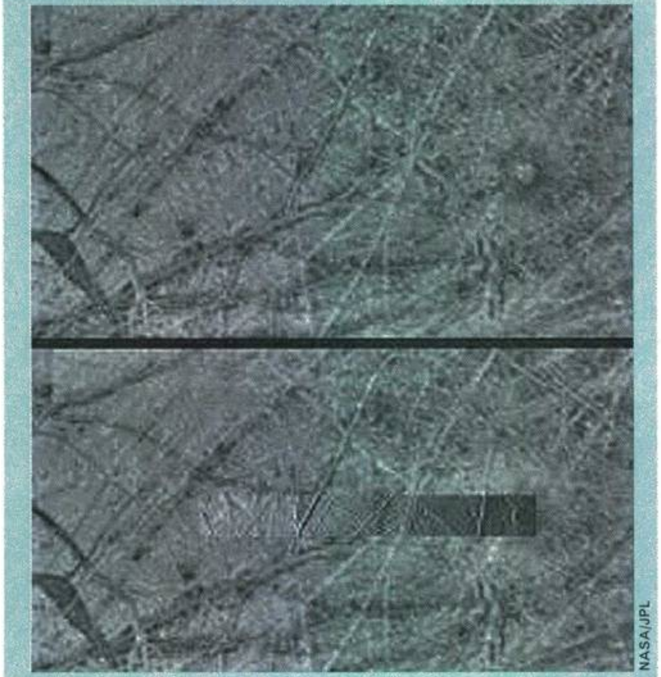
(Hale-Bopp)

The microscopic particles of dust reflect sunlight, causing the dust tail to glow a bright yellow. On the other hand, solar radiation ionizes the gas molecules (they lose one or more electrons) and the ion tail glows with a bluish color.

The newly discovered sodium tail stretches nearly 400,000 miles across and some 30 million miles long. While astronomers know that the electrically charged molecules in the ion tail are accelerated by the solar wind, no one has yet come up with a good explanation for how the neutral sodium atoms get transported into the tail.

GALILEO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EUROPA'S TANTALIZING TERRAIN **Changing lighting conditions help planetary scientists understand the topography of Jupiter's moon Europa. The Galileo spacecraft took the upper image on June 28, 1996, when the sun was nearly overhead. This lighting emphasizes albedo features, those regions that reflect different amounts of light.**

The higher-resolution inset in the lower image came when Galileo pointed its camera at the same area on November 6, 1996. At that time the region was illuminated from the side, equivalent to taking a picture from a high altitude near sunrise or sunset, which emphasizes topography. The bright linear regions in the upper image transform into ridges in the lower image. Cilix, the circular feature seen on the right side of both images, spans approximately 15 miles.

(What's Up?)
results, and if it is a real physical effect, further work will confirm it."

FILLING A GAP

New Planet in Corona Borealis

▶ The inventory of extrasolar planets keeps growing. A team of astronomers led by Robert Noyes of Harvard University has announced a Jupiter-mass planet orbiting Rho Coronae Borealis, a 5th-magnitude G0 star about 80 light-years away.

The planet, which was discovered by the same radial velocity technique used by most of the other planet-hunting teams, has a minimum mass of 1.1 Jupiters and orbits its star in a near-perfect circle at a distance of 0.23 AU, which would put it inside Mercury if it were in our solar system. At that distance, the planet races around the star every 39.6 days. Rho Coronae Borealis is slightly larger and hotter than the sun, and with an estimated age of around 10 billion years, it is considerably older. The sun will look a lot like Rho Coronae Borealis several billion years from now.

The planet seems to fill a gap. At a distance of 0.23 AU, it is not as close to its star as the four "hot Jupiters" — planets such as the one circling 51 Pegasi that orbit within 0.1 AU of their host stars. But compared with Jupiter and the planet orbiting 47 Ursae Majoris, it's still extremely close to its parent star.

Because planetary formation models predict that Jupiter-mass planets cannot form within 5 AU of their host stars, most astronomers think these close-in planets spiraled inward as they gravitationally interacted with their stars' protoplanetary disks. In the case of the four hot Jupiters, the planets spiraled so close that tidal interactions with the host stars probably circularized their orbits and also stopped them from plunging all the way into their stars.

But as Noyes points out, Rho Coronae Borealis's planet is far enough from its star that the tidal mechanism probably couldn't circularize its orbit. "This planet very likely started out with a circular orbit, which is a good reason to think that it formed from dust and gas in a protoplanetary disk," he says. "But if it then spiraled into the relatively close distance of 0.23 AU, why did it stop there?"

PUSHING THE FRONTIER

This Object Is Far Out!

Kuiper Belt object sets solar system record

▶ What's the most distant known object in the solar system? For the sake of fairness, let's not count comets such as Hale-Bopp that have highly eccentric orbits. But let's suppose we can count objects with moderately eccentric orbits. Using these criteria, the newly discovered 300-mile-wide object 1996 TL_{66} is the record holder. At its closest approach to the sun, TL_{66} comes almost as close as Neptune — 35 AU. But at its maximum distance, this ice world swings out to a whopping 132 AU — more

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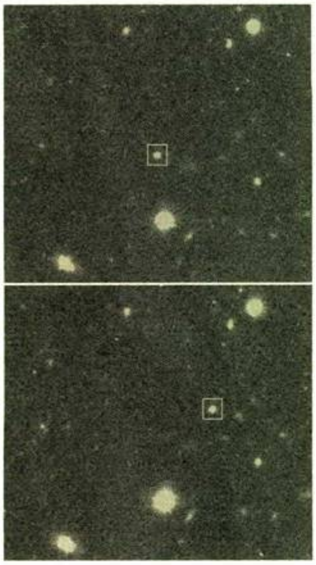
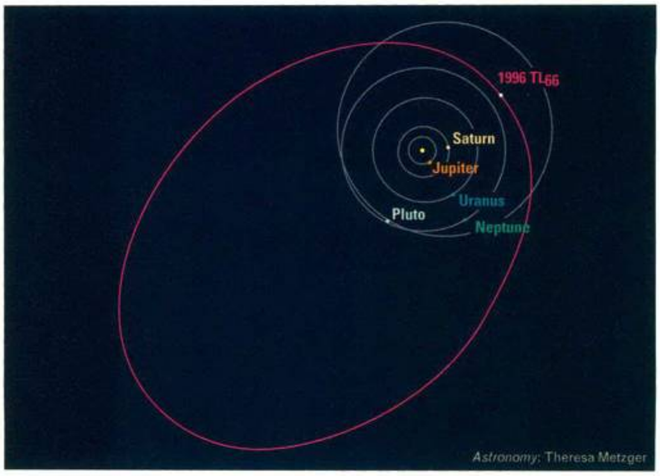
than four times Neptune's average distance from the sun. It takes this world nearly 800 years to complete a single orbit.

TL$_{66}$ was discovered in October 1996 by a team led by David Jewitt of the University of Hawaii and Jane Luu of Harvard University. This world belongs to the Kuiper Belt, a vast reservoir of icy mini-planets that starts just beyond the orbit of Neptune and extends to perhaps 150 to 200 AU. (Pluto is the largest member of the Kuiper Belt.)


David Jewitt (University of Hawaii), Jane Luu (Harvard University), et al.

Small and faint, 1996 TL$_{66}$ barely shows up on this discovery image made with the 2.2-meter University of Hawaii Telescope (above). The object's orbit carries it out to 132 AU, more than four times farther from the sun than Neptune (lower right).

All previously discovered Kuiper Belt objects inhabit a domain between 30 and 50 AU from the sun. The existence of TL$_{66}$ strongly implies that thousands of other objects lie at much larger distances, forming a whole new class of Kuiper Belt objects. In addition, the orbit of TL$_{66}$ is inclined 24° to the ecliptic plane. "TL$_{66}$ is orbitally distinct from all the other Kuiper Belt objects we have seen," says Jewitt. "It is one of about 10,000 similar objects that surround the solar system like a swarm of bees around their hive." Jewitt and his colleagues think TL$_{66}$ and its brethren formed just beyond Neptune but were scattered into more distant orbits through gravitational interactions with Neptune or with other large Kuiper Belt objects.



Astronomy: Theresa Metzger

LOCAL GROUP ADDITION

A New Local Galaxy

▶ With the Keck and Hubble Space Telescopes finding galaxies billions of light-years away, you'd think by now that astronomers would have a complete census of our own galaxy cluster, the Local Group. Think again. Most galaxies are intrinsically faint, and thus difficult to spot even when nearby. It came as no great surprise when British astronomers announced a new Local Group galaxy in April.

The new galaxy lies about 3 million light-years away in the southern constellation Antlia. Alan Whiting and George Hau of the University of Cambridge and Mike Irwin of the Royal Greenwich Observatory discovered the galaxy by using a special electronic instrument to discern faint, diffuse objects in photographs taken at the U.K. Schmidt Telescope in Australia. The team confirmed their finding with images taken at the 1.5-meter telescope at the Cerro Tololo Inter-American Observatory in Chile. In the same survey, the astronomers also discovered another relatively nearby galaxy lying about 11 million light-years away, too far to be a Local Group member.

Mike Irwin (RGO), et al.

The Antlia dwarf galaxy is the newest member of the Local Group. It is about 5,000 light-years across and contains 1 million stars, about the number found in a large globular cluster. The brightest stars in this image are foreground Milky Way stars. The individual stars seen in the Antlia galaxy are mostly red giants.

The Antlia galaxy is a dwarf spheroid galaxy about 5,000 light-years across with only 1 million stars (the Milky Way is 100,000 light-years across and holds about 200 billion stars). It is the 35th known member of the Local Group.

This dwarf is an outlying member of the Local Group, which means it hasn't interacted gravitationally with other galaxies. In contrast, most Local Group galaxies are satellites of the two large spiral galaxies that dominate the cluster, the Milky Way and Andromeda galaxies. Thus the Antlia galaxy gives astronomers a golden opportunity to learn how undisturbed dwarf galaxies evolve, which in turn will help them piece together the

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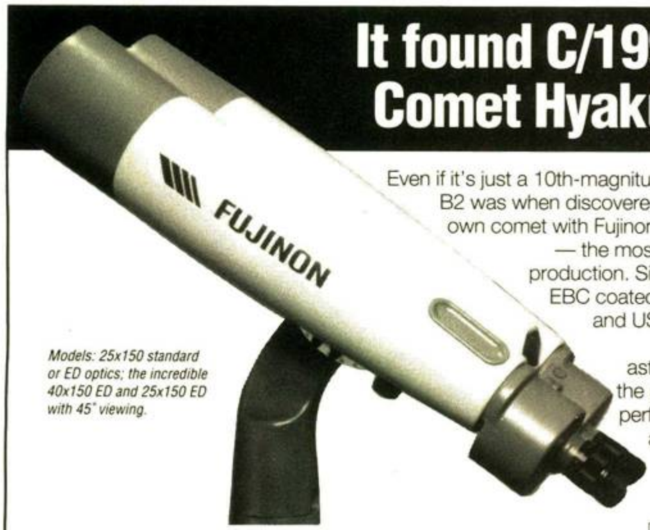
It found C/1996 B2, Comet Hyakutake



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story of how the Local Group has evolved over the past few billion years.

In the meantime, the British team is working to confirm other possible new Local Group members. "There are almost certainly other Local Group galaxies lurking out there waiting to be found," says Irwin.

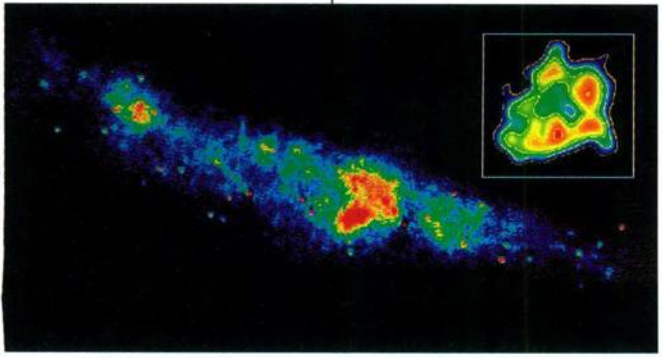
RADIO INTERFEROMETRY

Supernova Remnants in M82

▶ Using an array of radio telescopes, a team of astronomers from the University of Manchester in Britain has peered deep into the heart of M82, an irregular galaxy roughly 12 million light-years away in Ursa Major. M82 is a classic starburst galaxy, meaning it is undergoing extremely high rates of star formation. And wherever stars form in large numbers, the most massive are bound to explode as supernovae.

The team, led by Tom Muxlow, used a network of radio telescopes called MERLIN to peer through the thick dust of M82 to resolve the remnants of 50 supernovae, all of which are less than 1,500 years old. MERLIN consists of six telescopes around Great Britain that are linked together to form an interferometer. MERLIN's extremely high angular resolution — roughly equivalent to that of the Hubble Space Telescope — allowed the Manchester team to study individual supernova remnants in detail. Visible light cannot penetrate through M82's thick dust, so Hubble is useless for this kind of work.

Muxlow's team found that stars are exploding in M82 at a rate of one every 30 years, about three times the rate in our galaxy (which is much larger than M82). The team also found that M82's supernova remnants have the same spherical shell structure as many of their Milky Way counterparts. By looking at supernova remnants of various ages, the astronomers found that the remnants expand at a constant speed for hundreds of years before slowing down. The team is also using MERLIN to examine how the supernova debris interacts with the surrounding gas. By mapping and dating the various supernova remnants, the team hopes to determine the cause of M82's starburst activity.



Tom Muxlow, et al. (University of Manchester)

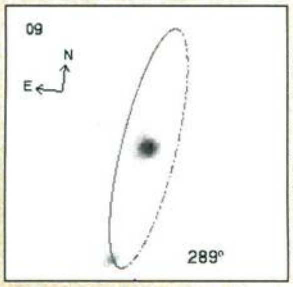
In this radio image of M82, red and yellow denote regions of intense star formation. By using a network of radio telescopes, British astronomers resolved individual supernova remnants in M82 such as this one (inset).

A New Black Hole?

In 1977, an x-ray nova flared in Ophiuchus. By analyzing the radial velocity of the companion star with the 10-meter Keck Telescope, a team led by Alexei Filippenko of the University of California at Berkeley reports in the April 1997 *Publications of the Astronomical Society of the Pacific* that the mass of the invisible member of the system is at least 4.9 solar masses, and probably between 6.4 and 6.9 solar masses. This is well above the 3.2-solar-mass upper limit for neutron stars, strongly implying that the invisible object is a black hole.

Pinpointing Pluto's Mass

For years astronomers have been trying to pin down the ratio between the mass of Pluto and its moon Charon. In the April 1997 *Icarus*, Jeffrey Foust of MIT and his colleagues, after analyzing a set of ground-based images, reported that Charon is 0.12 the mass of Pluto. This value is consistent with earlier results from the Hubble Space Telescope. This ratio, coupled with Pluto and Charon's individual masses and densities, points toward a collision origin for the system.



S. Alan Stern (SwRI), et al., and NASA

Pluto is 8.3 times more massive than its moon Charon.

Largest Centaur

James Scotti of the University of Arizona has found possibly the largest Centaur discovered to date. Centaurs are small, comet-like bodies that orbit the sun between Saturn and Neptune. The new Centaur, tentatively called 1997 CU_{26}, is slightly brighter, and thus probably slightly larger, than the previously largest known Centaur, Chiron, which is about 125 miles in diameter. CU_{26} is the seventh known Centaur and orbits the sun at an average distance of 15.9 AU.

Neutron Star Consuming White Dwarf

In the core of the globular cluster NGC 6624 lies a pair of stars emitting intense ultraviolet and x-ray radiation. The white dwarf and neutron star whip around each other in just 11 minutes, the shortest period of any known binary. Now recent Hubble observations by Scott Anderson of the University of Washington and his colleagues confirm that the ultraviolet emission varies with the same 11-minute period. Astronomers speculate that the neutron star sucks material from the white dwarf, producing x rays that then strike the white dwarf, heating it to produce the ultraviolet light.

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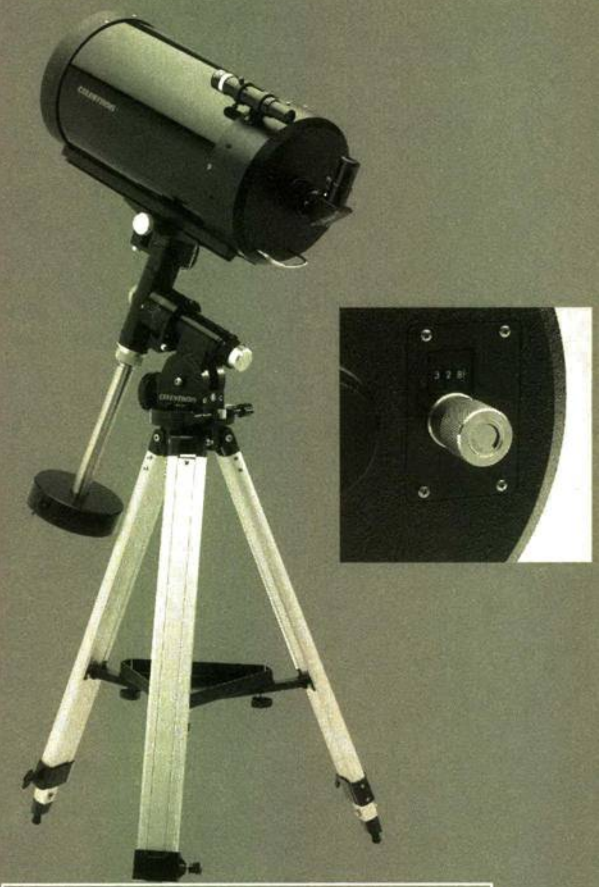

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SPECIAL REPORT

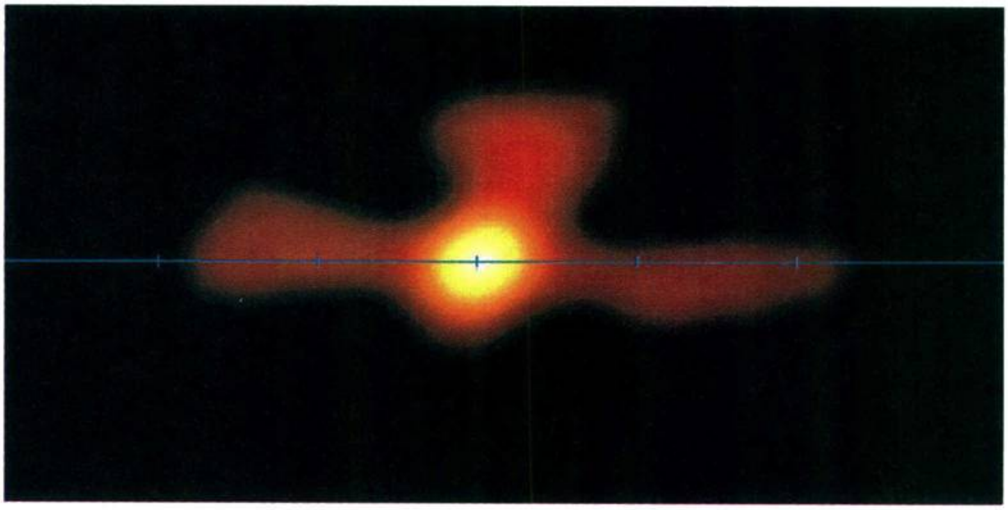
The Dangers of Urban Life

Cloud of antimatter discovered in Milky Way

▶ Human beings should feel thankful that we live on a rock well out in the galactic suburbs. Some 30,000 light-years from the Milky Way's center, our neighborhood is relatively quiet, existing peacefully in a spiral arm peppered with occasional star clusters and nebulae but devoid of any highly energetic troublemakers.

For years astronomers have suspected that trouble lies deep down in the heart of the Milky Way's core, galactic central city, where the jam-packed environment is powered by a massive black hole. But at the Fourth Compton Symposium on Gamma Ray Astronomy, held in Williamsburg, Virginia, last April, it suddenly became clear that the busy, central part of the galaxy is a dangerous place for a second reason: the presence of a huge fountain of antimatter.

"It's like a torch rising from the center of our galaxy," says Charles Dermer of the Naval Research Laboratory, one of the team that reported the startling result. The cloud of antimatter floats some 25,000 light-years away from us, measures 4,000 light-years across, and lies about 3,500 light-years above the plane of the galaxy.



Gamma-ray radiation shows where positrons are being annihilated in the Milky Way. Astronomers expected to see bright emission from the galaxy's core and disk, but the plume of antimatter rising north from the galaxy's center was a surprise. NASA/GRO

The antimatter cloud consists of positrons, the antiparticle of the ordinary electron. When a positron encounters an electron, they annihilate one another, producing a pair of gamma rays at an energy of 511,000 electron volts. The team used the Oriented Scintillation Spectrometer Experiment (OSSE), one of the instruments onboard the Compton Gamma Ray Observatory, to detect and map the antimatter. The rate of annihilation is staggering: some $7\text{x}10^{42}$ positrons per second. Although each photon of radiation is about 250,000 times as energetic as a photon of visible light, the overall effect on Earth is far less than the contribution by the even more powerful cosmic rays.

Where the antimatter comes from remains to be seen. "It's a mystery," says William R. Purcell of Northwestern University, another team member. Adds fellow researcher James D. Kurfess of the Naval Research Lab: "The antimatter cloud could have been formed by multiple star bursts occurring in the central region of the galaxy, jets of material from a black hole near the galactic center, the merger of two neutron stars, or it could have been produced by an entirely different source."

Though several possibilities exist, the feeling I got at the meeting was that the galaxy's central black hole engine is the leading candidate. "Black holes probably make positrons, so they may act like antimatter factories," says Dermer. Although the black hole believed to be in the Milky Way's center probably holds about one million solar masses, it's probably in a quiescent stage right now. It's pretty much dormant compared with the highly energetic supermassive black holes in the centers of many active galaxies observed throughout the universe. But it may well serve as an accelerator that produces the fountain of antimatter observed by the Compton team.

Of course OSSE detects the antimatter positrons only where they're being annihilated by combining with electrons — vast numbers of additional positrons may exist around the cloud but isolated from normal matter. The finding has astronomers at least in part reinterpreting the structure of the Milky Way Galaxy and the implications for other galaxies. "It's like finding a new room in the house we have lived in since childhood," says Dermer. "The discovery changes our understanding of the home galaxy."

Although Compton has produced many important scientific results, it is the antimatter fountain that has grabbed most of the recent glory. Perhaps it was the irresistible notion about how intergalactic travelers would be threatened not only by the black hole at the Milky Way's center, but also by a tower of positrons that if combined with their electrons would do them a great disservice. Or perhaps it was simply the comforting notion of our own place in the galaxy. After years of thinking about being stuck out in the burbs, where nothing exciting takes place, we're learning that's not such a bad thing after all.

— DAVE EICHER

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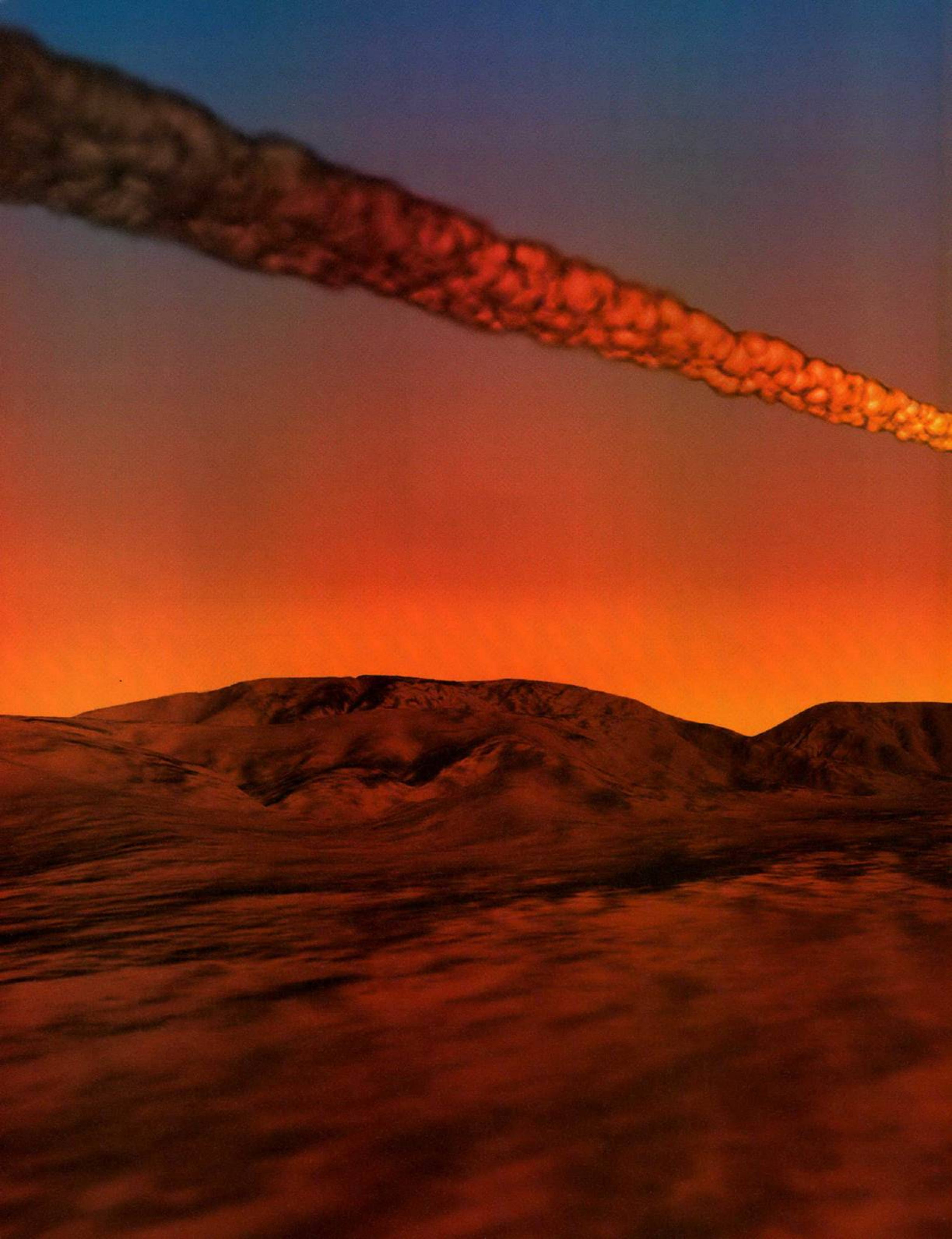


THE NEW MARTIAN CHRONICLES

Humanity could look back upon 1996 as the dawn of a new Mars.

by David S. F. Portree

THE MARTIAN CENTURY. THAT'S WHAT FUTURE HISTORIANS might call the 21st century. They might record it beginning a few years early, on August 6, 1996, when scientists announced evidence of possible ancient life in a martian meteorite. They might look back on the first footprints in Mars's red sands, the first outpost, and a definitive answer to the ancient question of life on Mars. Perhaps they'll even record this history from Mars, as martian settlers contemplate remodeling their home planet into a new Earth.

Until last August, astronauts and engineers alike officially downplayed the notion of a Martian Century. But now, thanks to a Mars meteorite the size of a potato, NASA has embraced Mars with all the ardor a financially strapped government agency can muster. Speaking at the December meeting of the American Astronautical Society in Houston, the agency's number-three man Michael Mott said, "Mars should be the crown jewel of the future exploration of space . . . the best space exploration tool is a pair of eyes looking through a space helmet visor." At the same gathering of aerospace professionals, Elric McHenry, manager of NASA's Advanced Projects Office, went even further, stating that, "eventual Mars settlement . . . is a guiding principle of our current planning."

Such bold pronouncements suggest there's a target date for human trips to Mars. In reality, the agency has postponed any decision until at least 2004, when the current series of Surveyor spacecraft end their cycle of exploration. With that in mind, a Mars "grand design" is forming throughout NASA to reduce the costs of a piloted Mars flight. These efforts might culminate in a permanent martian outpost by 2011.

A blaze of meteoric glory marks the arrival of a human expedition to Mars.

The first Mars habitat gets tested as an attachment to the International Space Station.

Mars Habitat Testbed

All illustrations: Kent Joosten/NASA-JSC

To Mars One Hurdle at a Time

But major challenges stand between the dream and its reality. Travelers to Mars will have to cope with low levels of gravity for a long time, avoid large doses of radiation, deal with a chemically reactive martian soil, and perhaps even ward off contamination by martian life. But according to Michael Duke, a scientist at the Lunar and Planetary Institute in Houston who has long been involved in Mars mission planning, the biggest challenge might come from robots. "We need to demonstrate a need to send people," Duke says. "It is no longer considered sufficient to propose human exploration based on excitement."

Duke is confident, however, that astronauts will win the day. "Humans will substantially accelerate the rate at which we can learn about Mars," he says. He cites the example of a robotic sample-return mission. Such a mission needs years to plan, build, and launch, followed by a six-month flight to the Red Planet, almost two years on the surface, and then a six-month return to Earth. After flight, the samples would still have to be analyzed. More years would pass before any follow-up missions could be mounted to explore any questions the first mission raised.

A piloted expedition, on the other hand, might require more time to plan and build, but it would also perform more science on Mars before returning to Earth. If explorers dug up something interesting, they would collect follow-up samples the following day, not years later. "Humans could do the same science on Mars in one or two years as robots could do in 100 to 200 years," Duke says.

Though proponents of piloted Mars exploration traditionally see robots as competitors, Duke says there is a "strong connection between humans and robots in piloted exploration." For example, robot trailblazers might test equipment and materials for space suits and human habitats. Already, a Mars Surveyor lander scheduled for 2001 will carry a suitcase-sized package to evaluate martian air for making propellant.

Of course, no matter how much testing is done, human exploration will carry risks. As John Charles, a NASA medical researcher who supervises biomedical experiments on Russia's Mir space station says, "Explorers have to be adventurers. Exploration is dangerous. That's life."

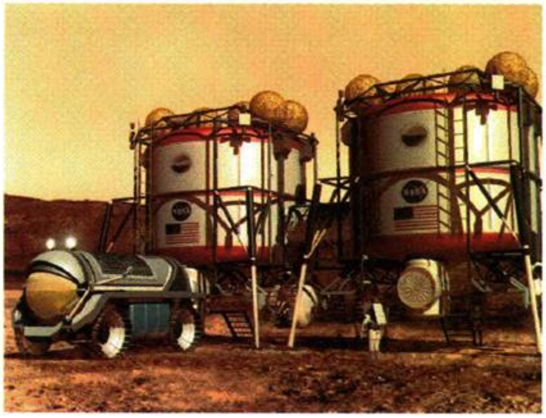
After working with astronauts for 10 years, Charles sees no biomedical roadblocks to Mars travel. But astronaut bodies will undergo changes. For example, in weightlessness travelers will lose bone density at the rate of about one percent per month. Earth's gravity restores bone mass, but structural changes persist after astronauts return to the ground. Biomedical studies slated for the space station, which is set for completion by 2003, should provide more data on the effects of long-duration weightlessness and let physicians perfect countermeasures. Charles already prescribes countermeasures which have proven effective for astronauts during long stays on the Mir space station — rigorous daily exercise, plenty of fluids, and salt tablets.

But how will Mars's gravity, one-third that of Earth's, affect astronauts? "I think that they'll continue to lose bone density, probably at a reduced rate," Charles says. Then there's the matter of disorientation. The human vestibular function — the system that maintains balance and judges orientation — gets knocked for a loop in weightlessness. For this reason, Charles argues for an automatic pilot on martian landers. He even prescribes holding off that first Mars walk for a few days until the astronauts recover from the effects of weightlessness. "They'll deserve a few days off to look out the window after flying all the way to Mars," he says.

One other long-term factor weighs heavily on the minds of Mars mission planners. Astronauts will be exposed to possibly high levels of radiation during a flight to Mars. Kent Joosten, an exploration engineer at NASA's Johnson Space Center in Houston, is part of a team that's putting radiation dosimeters on a Mars Surveyor lander set to fly in 2001. They will provide data on what radiation levels a Mars expedition might encounter.

Beyond that, Joosten says no standards exist for governing safe levels of radiation exposure during interplanetary flight. Shuttle astronauts in Earth orbit are statistically lumped into a category that includes nuclear power plant workers. So-called radiation workers might see a 3% increase in mortality. By necessity, the level of acceptable radiation exposure might have to be set higher because interplanetary explorers are outside of Earth's protective magnetic cocoon. Even then, radiation is unlikely to be ranked above other risks. Charles notes that, "with radiation, at least, we can devise engineering solutions." He suggests arranging an expedition's cache of food and water to act as radiation shielding.

More than radiation, Joosten is concerned with the infiltration of martian dust, which both Viking landers showed was highly reactive when exposed to water. "We will fly an experiment that exposes martian dust to a wet, warm, oxygen atmosphere, like that inside a Mars habitat," he says. Fine-grained martian dust will inevitably enter any outpost humans establish on Mars. For one thing, astronauts will track it in on their space suits. "It will be a mess," Joosten says, "and could present a real problem if it's toxic." The 2001 Surveyor might also evaluate experimental dust filters.



Mars explorers have all the comforts of home, albeit spartan. Landers provide food, fuel, and shelter. A rover gives expeditioneers mobility.

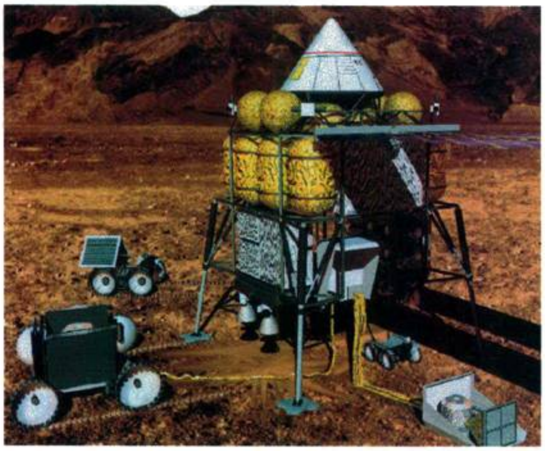
Tracking in dust could also lead to an invasion of any martian microbes present in the soil. James Gooding runs the laboratory at NASA's Johnson Spaceflight Center that stores and studies moon rocks collected by the Apollo astronauts 25 years ago. Gooding says NASA has adopted a "conservative approach" to handling Mars materials to avoid "back-contamination" — that is, the accidental releasing of possible martian organisms on Earth.

According to Gooding, "the best approach to designing back-contamination controls is to perform meaningful reconnaissance of the Mars surface environment before we send the astronauts. The more we know about martian materials, the more effective will be our provisions for the astronauts." Gooding's already planning for NASA's proposed robotic sample-return mission in 2005. "We are now busy identifying sample handling protocols," he says. "A few robotic sample returns will make us immensely wiser about how to send people to Mars and return them safely."

So NASA's philosophy is that while it cannot predict or avoid all risks, it can learn enough about Mars in the near future to consider reasonable precautions. As Joosten puts it: "The first people to go to Mars will encounter unknowns because they'll be doing something no one has ever done before — exploring another planet."

The last word on risk comes from someone who might face the danger first hand. Tom Jones is a veteran Shuttle astronaut who works closely with the JSC Mars team. Members of his 1990 astronaut class wore a cloth patch that showed the moon and Mars because they hoped to visit both places. Jones, a geologist whose life would be on the line during a Mars mission, says "we can do a Mars mission with what we know now. If the goal is to send people to Mars to look for life," he says, "then let's send people to Mars."

An automated station lands two years before humans arrive to make fuel for the return trip to Earth.



Where There's a Will . . .

So how will the first humans get to Mars? NASA answered that question 10 years ago when it trotted out a 30-year, $300-billion man-on-Mars program based on plans drawn up during the blank-check days of the 1960s. Dozens of Shuttle flights would launch components and fuel for giant spaceships assembled near a large Earth-orbiting space port. After arriving at Mars, three astronauts would spend only 30 days (out of an 800-day mission) exploring the surface while three others stayed in orbit.

Predictably, few were happy with the plan's expense, complexity, long timeline, and the short time it provided for exploration of the martian surface. So in August 1990 Robert Zubrin and David Baker, engineers at Martin Marietta in Denver, proposed a controversial alternative: the Mars Direct mission plan.

Zubrin's Mars Direct contains conceptual breakthroughs that make a manned mission simpler, cheaper, and more effective. It uses a different trajectory to get a crew to Mars in just six months. Once there, astronauts would explore the Red Planet for 500 days while waiting for the planets to line up for a six-month return to Earth. Astronauts wouldn't linger in martian orbit — they would head down to the planet's surface, where they would dig in to escape radiation exposure.

Zubrin's plan uses two different landers. A Habitat lander transports the crew to Mars and houses them on the surface, while an Earth Return Vehicle carries them home. The landers are small, about 40 tons each, or around half the weight of the Space Shuttle orbiter.

Most important, though, is Zubrin's reliance on martian resources. The Habitat lands on Mars with empty fuel tanks. The Earth Return Vehicle, which is sent two years ahead without crew, manufactures 107 tons of methane-oxygen fuel for the trip home by combining martian air with six tons of liquid hydrogen brought from Earth. This might sound like sleight-of-hand, but it's just 19th-century industrial chemistry.

Others had proposed making fuel on Mars before Zubrin, but no one called for such a profound reliance on martian resources. Using martian fuel for the trip home cuts the amount of weight launched from Earth. Two big rockets would be sufficient to launch Zubrin's expedition directly to Mars, with no Earth-orbital assembly.

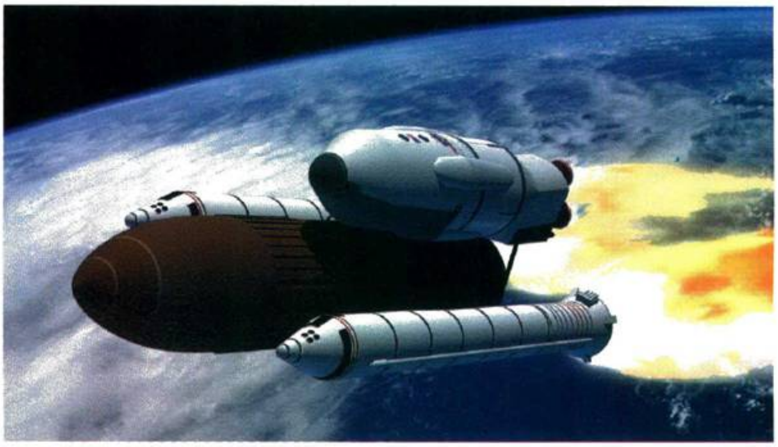
According to Joosten, Mars Direct's concepts are "parables . . . that is, good lessons, good ideas to look at, but not necessarily correct in their details." In 1993, JSC planners modified some of Zubrin's details to come up with their version of Mars Direct. It's called Mars Semi-Direct, and is the point of departure for current NASA Mars mission planning.

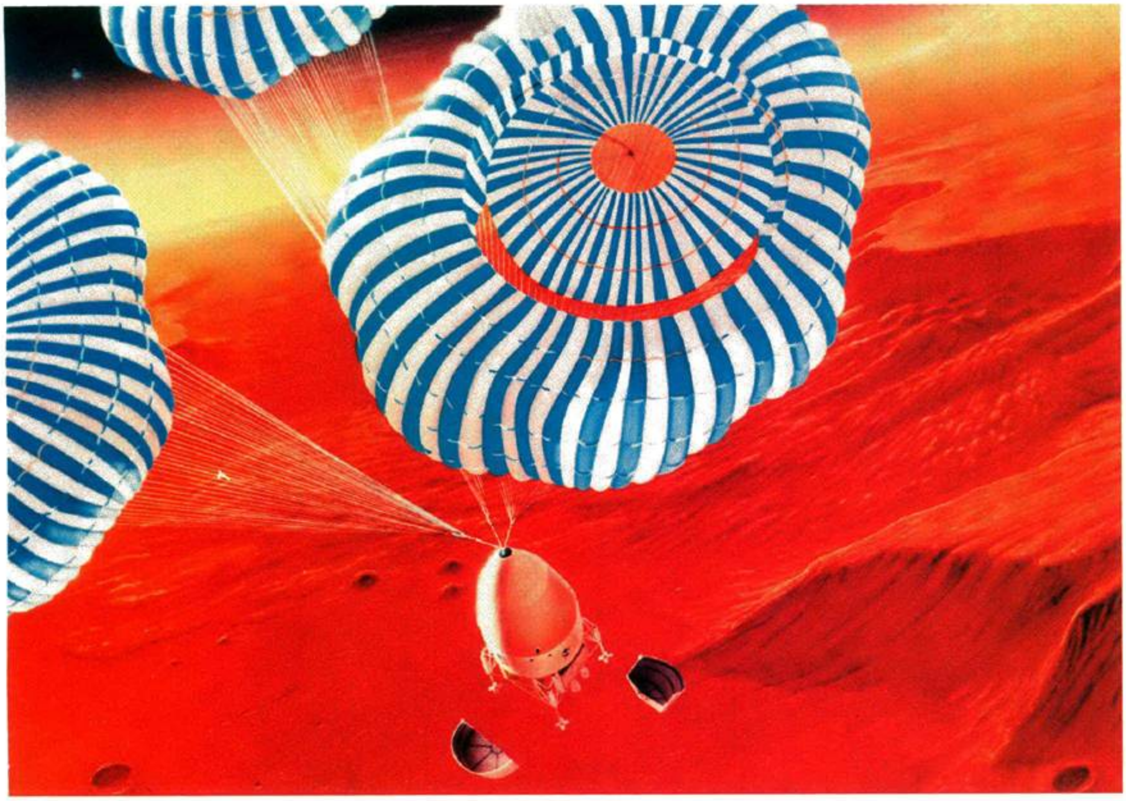
Every spacecraft in Mars Semi-Direct has a backup, so the plan is less risky than Mars Direct. In addition, the Earth Return Vehicle never lands on Mars. It stays in Mars orbit, where the crew reaches it using a Mars Ascent Vehicle powered by martian fuel. NASA's 1993 plan uses three Saturn V-class rockets, one each for the Surface Habitat, the Earth Return Vehicle, and the Mars Ascent Vehicle/Fuel Factory.

In late 1996, the JSC team removed a weak link in the Mars Semi-Direct plan by eliminating the need for an expensive heavy-lift rocket. Their amended plan launches smaller landers on what are called Shuttle-C rockets. Instead of a winged, piloted, reusable orbiter, Shuttle-C mounts a wingless, throwaway version of the shuttle orbiter on a standard shuttle external fuel tank and two solid rocket boosters. While the shuttle can put 20 tons into orbit, Shuttle-C could launch 80 tons by sacrificing reusability. An industry study in the early 1980s estimated that Shuttle-C could be ready for flight in two years at a development cost of about $1.5 billion in early-1980s dollars.

In the latest plan, six Shuttle-C rockets launch the Surface Habitat, Earth Return Vehicle, Mars Ascent Vehicle/Fuel Factory, and three nuclear

A modified Space Shuttle boosts the building blocks of a human expedition to Mars.





Chutes pop, landing gear deploys . . . What brave, new world awaits the first intelligent martians?

propulsion stages. Each payload is joined to a propulsion stage in Earth orbit, and then boosted toward Mars.

For their study, the JSC engineers chose 2011 as a target date for launching the first crew toward Mars. That's when Earth and Mars line up to allow a travel time of less than six months. Because Mars's orbit is eccentric and tilted relative to Earth's orbit, it turns out that 2011 isn't the best of opportunities, which is one reason why the JSC team chose it for their mission studies. "If we can design a mission for that opportunity," Joosten says, "we can design one for any opportunity." That's important, because teams of astronauts will have to leave each time Mars and Earth line up, roughly every 26 months, to build and maintain a Mars outpost.

A permanent outpost on Mars sounds like a big-ticket item, but Joosten says that NASA is working hard to lower the costs of piloted Mars exploration. He believes that design innovations will eventually allow NASA to establish and expand a Mars outpost for about $2 billion a year — similar to what's being spent now to build a space station in low-Earth orbit.

Will Lightning Strike Twice?

So just how close are we to seeing humans stride confidently over the red sands of Mars? NASA is sending new robots to answer fundamental questions about the planet. It's even settled on a basic plan for a piloted Mars expedition. It's still more expensive than its designers want, but much cheaper than the one floated 10 years ago.

Despite the gathering momentum, few people believe we will land humans on Mars within the next ten years. This could be because they've forgotten history. On May 5, 1961, two weeks before Kennedy set one of the boldest goals in human history, Alan Shepard became the first American in space. "I had no idea that Kennedy would put us on the road to the moon two weeks after my first flight," he recalls. On his second flight, ten years later, Shepard commanded the Apollo 14 expedition to the moon. The lesson of Shepard's experience is that there's no way to predict when the lightning of political support will strike life into a program. In the case of piloted Mars exploration, it might happen this year — or never.

Assume for now, though, that getting humans to Mars will become a national priority sometime in the early 21st century. Assume that settlers follow the explorers. Now, look a century beyond the first Mars landing. For settlers, the first landing's anniversary will be a planetary holiday. During the celebrations, few will recall today's unglamorous preparations, any more than most of us consider Columbus's struggle to secure funding from the crowned heads of Europe in the 1480s. To our descendants on Mars, the important thing will be that we came to Mars — that we decided to make the 21st century the Martian Century. **A**

David S. F. Portree (dsfportree@aol.com) is a science writer in east Texas. He publishes Romance to Reality, *an on-line guide to lunar and martian exploration plans (http://members.aol.com/dsfportree/explore.htm).*

Looking for

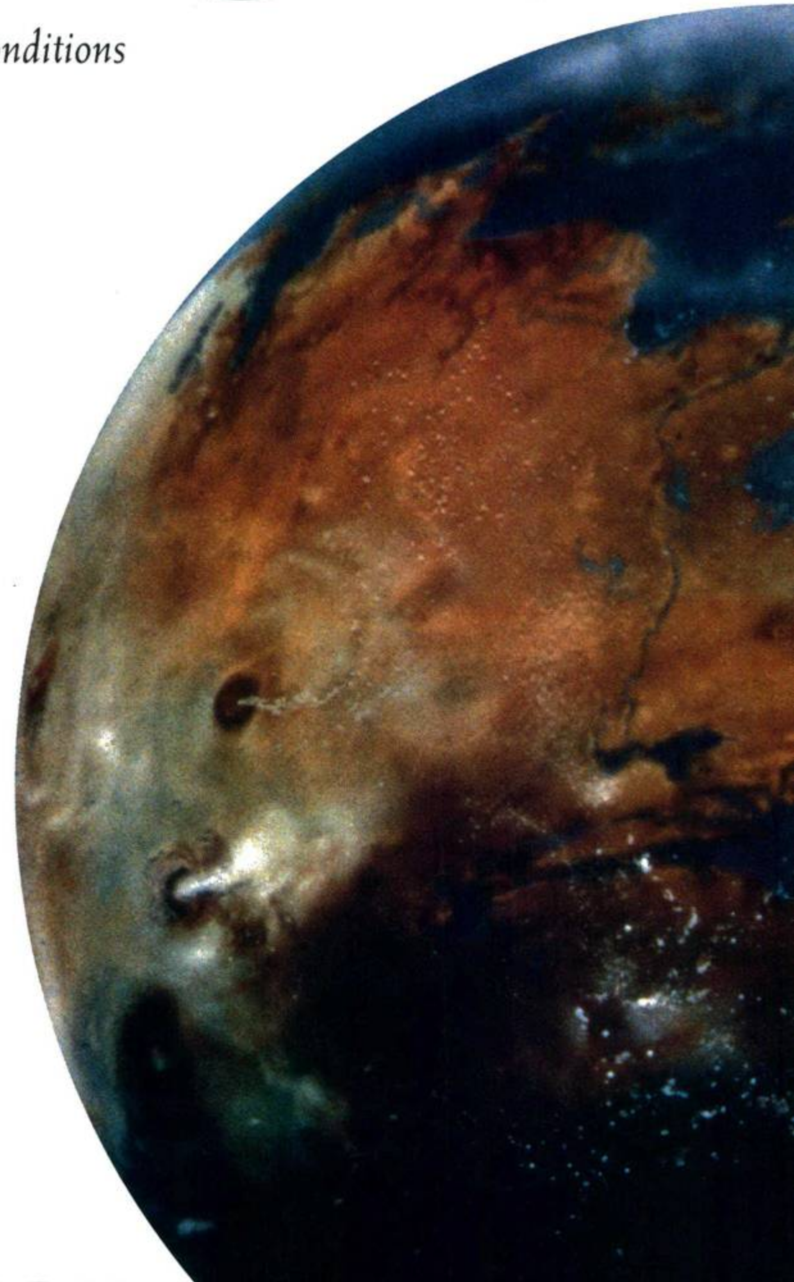
Billions of years ago, conditions on Mars were ripe for life. Where should we search for evidence?

When scientists proclaimed a year ago that organisms may once have lived on Mars, the public reacted with unbridled excitement. In fact, few moments in the history of science captured people's imaginations as much as the announcement of possible fossilized life forms in the previously obscure martian meteorite ALH84001.

The evidence in the meteorite consists of intriguing microstructures that could be microscopic fossils of life on Mars from billions of years ago. But the evidence is not compelling — the structures could be biological in nature but they could just as well be mineral. To find convincing evidence for past life on Mars, scientists or their robot surrogates probably will need to visit places on the martian surface where life was abundant and conditions were right for preserving fossils. Fortunately, we can already identify some promising locations and approaches for finding evidence of past life.

The Mars of Long Ago

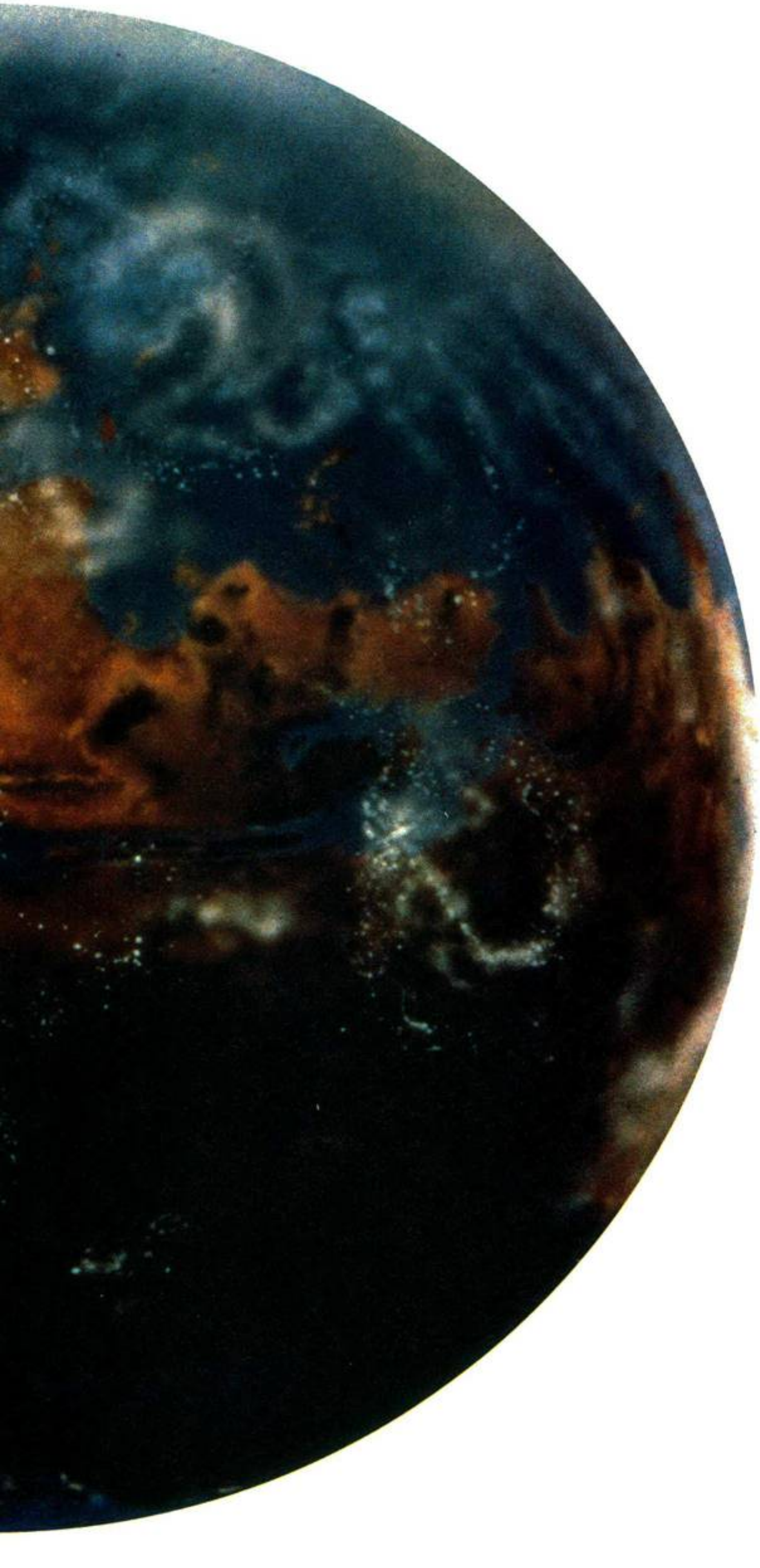
Even before the structures were found in the martian meteorite, interest in the question of life on Mars was growing because of both a deeper understanding of the early martian environment



The watery Mars (right) that existed 3.5 billion to 4 billion years ago may have been conducive to the genesis of life. Scientists are now pondering whether life got started and, if so, where on Mars to search for the proof.

W. Schopf; CENTER: Michael Carroll

Life on Mars

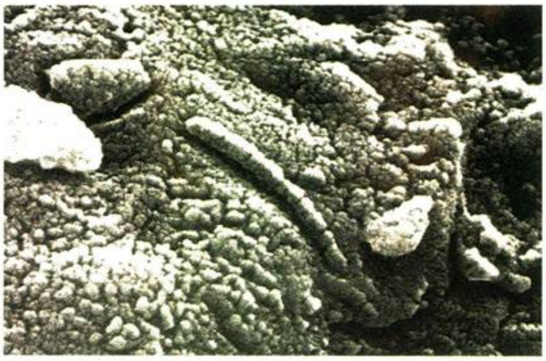


by Christopher P. McKay

and new discoveries about the origin and limits of life on Earth. Images taken by the Viking orbiters in the 1970s revealed long river channels on Mars, proving that liquid water flowed on the planet's surface at least once in the past. The cold, dry Mars of today contrasts sharply with the warmer, wetter conditions that must have been present at those times. The majority of the fluvial features on Mars lie in ancient cratered terrain more than 3.5 billion years old.

That's a significant age because on Earth definite fossil remains of life, similar to filamentous algae alive today, exist from 3.5 billion years ago. (Chemical evidence shows that life may have been present as long as 3.9 billion years ago.) Structures within these 3.5-billion-year-old fossils show they have a clear biological origin. The same cannot be said of the possible microfossils in the martian meteorite. These fossils are simply tiny egg-shaped objects that contain no convincing biological structures or patterns. To make the case for life on Mars we need better samples, samples that include fossils of the quality that were used to make the case for life on Earth 3.5 billion years ago.

Life certainly existed on Earth 3.5 billion years ago, as a microfossil from that time (opposite page) attests. Scientists still debate whether the possible microfossil found in a martian meteorite (below) signifies life.



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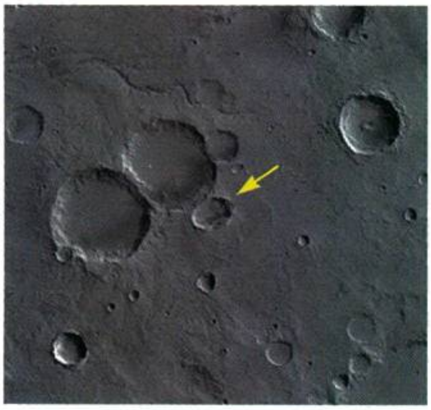
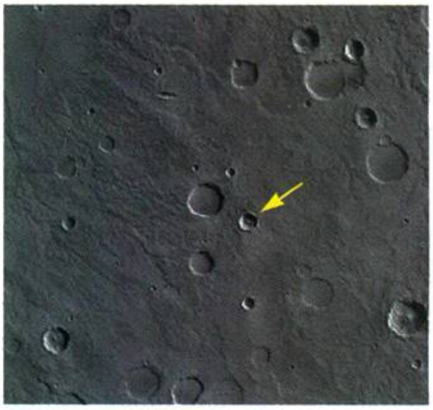


USGS Division of Astrogeology/PDS Imaging Node

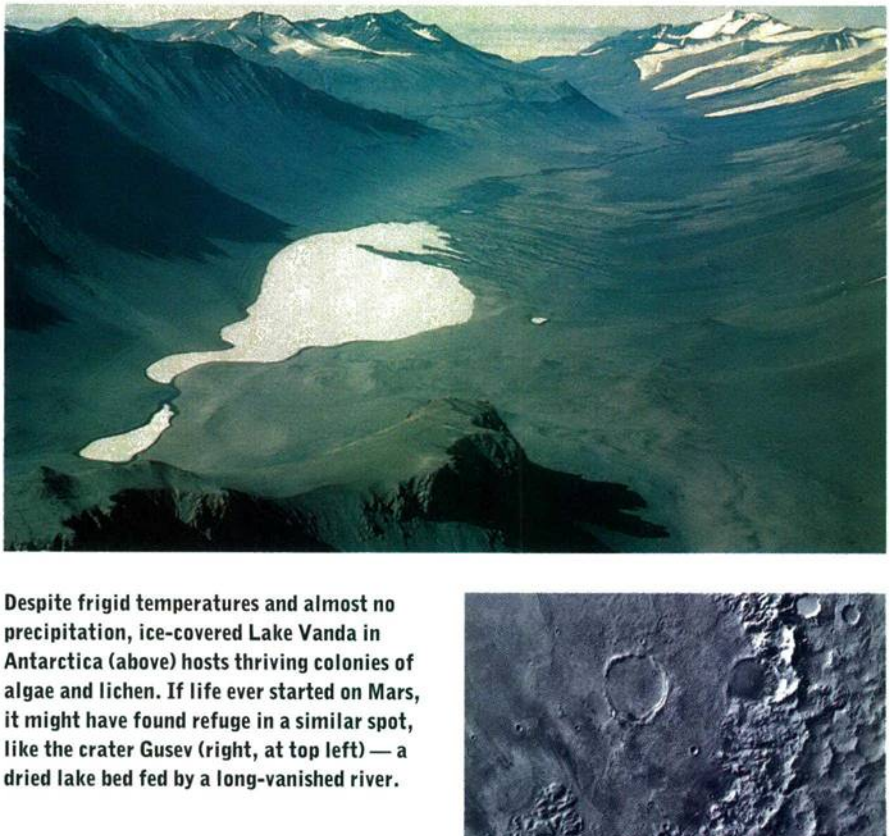


USGS Division of Astrogeology/PDS Imaging Node

One of the two craters marked by arrows could be the site of the impact that launched ALH84001 to Earth. Visiting those sites could provide more evidence for fossil life on Mars, but it could prove just as inconclusive.

Perhaps other rocks from the same site as ALH84001 would hold more conclusive evidence for life. Scientists know that the meteorite came from the ancient cratered terrain and formed about 4.5 billion years ago. Then some 15 million years ago an impact launched the rock onto its eventual collision course with Earth. But where *exactly* did the meteorite originate?

Nadine Barlow, an expert on martian craters from the University of Central Florida, has scoured the planet's surface looking for craters that could mark the impact site. She identified two that are both about the right size (roughly 10 km across) and right age. Both craters also appear slightly oblong, indicating a glancing impact. (Glancing impacts are more efficient than direct blows at launching rocks off a planet.) If we returned a sample from a site near where ALH84001 originated, we could be pretty confident that the sample would contain evidence similar to that found in the meteorite. But such a sample would not likely contain any evidence for life more definitive than what we already have. To find such evidence requires going to a site better suited for life, and fossil formation, than the plains in the ancient cratered terrain.



R. Vestal

NASA/JPL

Despite frigid temperatures and almost no precipitation, ice-covered Lake Vanda in Antarctica (above) hosts thriving colonies of algae and lichen. If life ever started on Mars, it might have found refuge in a similar spot, like the crater Gusev (right, at top left) — a dried lake bed fed by a long-vanished river.

Ancient Lake Beds

Arguably the most promising site to search for martian fossils would be in an ancient dried lake bed. First, lakes could have provided a habitat for life long after conditions on dry land became inhospitable. Second, the sediments on the bottom of a lake bed provide an excellent way to trap and preserve fossils. Third, and most important, a large, flat lake bed offers an easily identifiable and practical target for a sample return mission.

The dry valleys of Antarctica prove the value of an ice-covered lake as a habitat on a cold planet. With an average temperature of –20° C (–5° F) and only about 2 cm (less than an inch) of precipitation a year, all in the form of snow, these valleys are the most Mars-like places on Earth. The environment is too harsh to support life. However, huge sheets of ice several meters thick lie on the valley floors. Water exists beneath the ice, and in the water microbial life flourishes. Robert Wharton of the Desert Research Institute of the University of Nevada, Reno, and his colleagues have studied these lakes as analogs for ice-covered lakes on early Mars. Models of the martian climate suggest that long after conditions on the surface became too cold and dry for life, ice-covered lakes could have provided a final refuge. As life died out, it would have been preserved in the sediments on the bottom of the lake.

Hebes Chasma — a deep canyon with a large plateau in it — may be one such dried lake bed. Layers on the sides of the plateau, as well as in other sediments in the canyons of Valles Marineris, appear to have been deposited in standing bodies of water. The presence of water is consistent with the general geology of the area, which suggests to planetary scientist Mike Carr of the U.S. Geological Survey that ground water drained from the Tharsis uplands to the northern plains for an extended period of time in martian history. As this ground water flowed, Hebes Chasma would have been filled with water, presumably with a relatively thin layer of ice on the top. As in the Antarctic dry valleys, life might have persisted under this ice cover long after it came to an end on the adjacent plains.

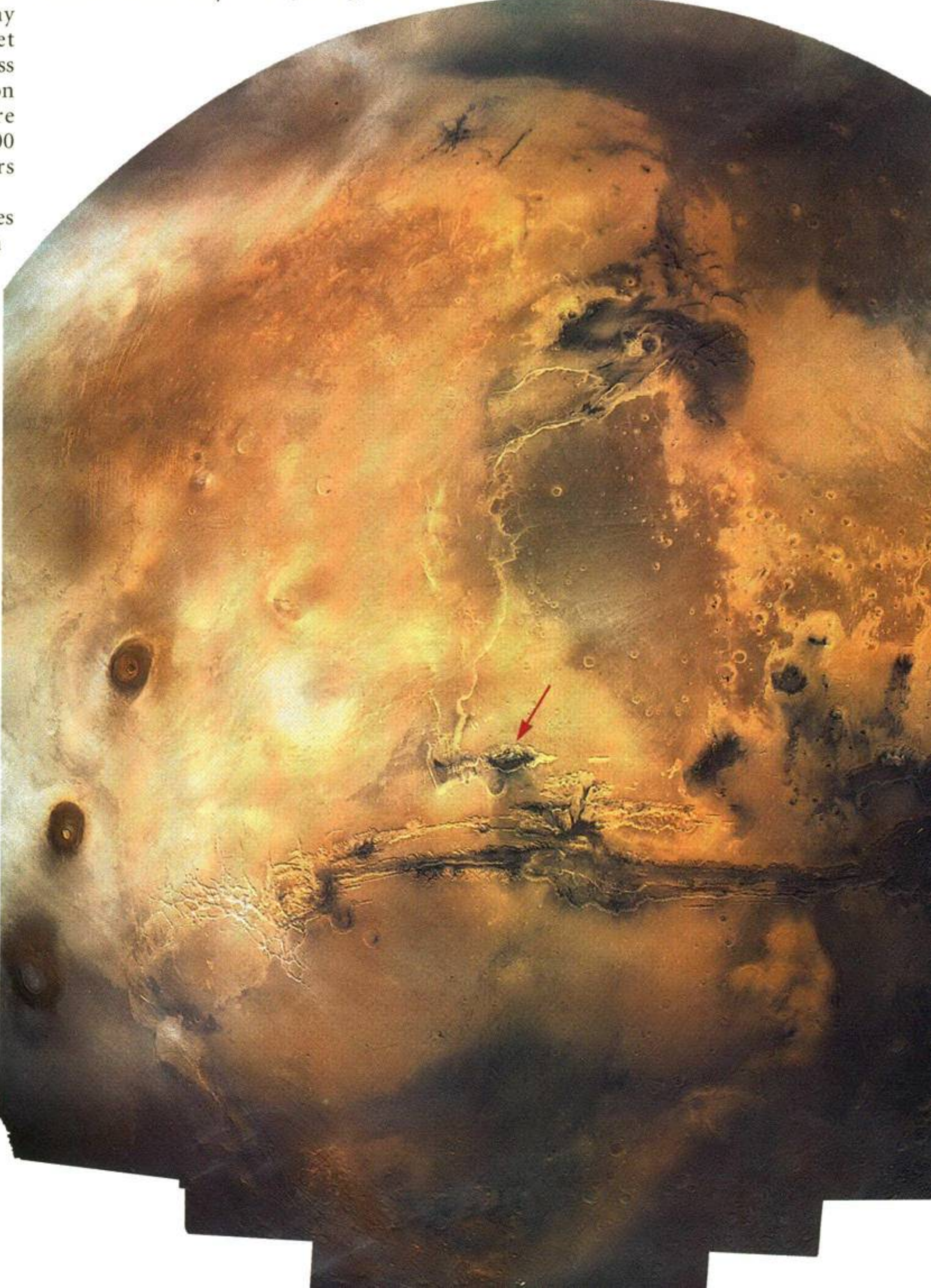
Unfortunately, Hebes Chasma presents a formidable challenge to any future space mission. The target plateau measures just a few miles across and the precipitous walls of the canyon drop several miles. Landing there would require a precision almost 100 times better than the present Mars Pathfinder mission can muster.

But other, more practical, lake sites could be targeted by a sample return mission. The crater Gusev makes a particularly attractive candidate. A large river once flowed into this 35-mile-wide (60 km) crater, creating a lake in the crater and carrying in sediments that filled the crater's floor. The result: a large, flat plain that provides an easy-to-target landing site and easy terrain for a rover to navigate. Mission controllers could land a rover in the crater's center, then move it toward the shoreline and up the riverbed, all the while searching for fossils in the sediments.

Hydrothermal Springs

Another possible site to search for ancient martian life would be former hydrothermal springs. In these springs, hot water from deep within the planet rises to the surface and cools quickly. Under such circumstances, the minerals dissolved in the hot water rapidly precipitate, or separate out as solids, efficiently preserving as fossils any life forms in the water. Malcolm Walter of Macquarie University in Australia and David DesMarais of NASA's Ames Research Center suggest that hydrothermal springs could be ideal locations to search for well-preserved fossils on Mars. On Earth, however, hydrothermal springs usually lie at temperate latitudes, raising the question of whether they would behave similarly on a cold world like Mars. Recent reports of hydrothermal springs in the high Arctic by Wayne Pollard of McGill University and his colleagues may help alleviate this concern. These springs emerge through more than 1,600 feet (500 meters) of permafrost. Although the water that comes out is only 5° C (40° F), it is 25°C (45° F) warmer than the permanently frozen ground around it. Like their counterparts in temperate regions, these springs generate mineral deposits that trap and fossilize microorganisms.

Because hydrothermal springs derive their energy from geothermal sources, they could survive on Mars long after other liquid water habitats — even longer than ice-covered lakes. Virginia Gulick of NASA Ames has shown that hydrothermal systems could even be operating in the present martian climate and that such systems heated

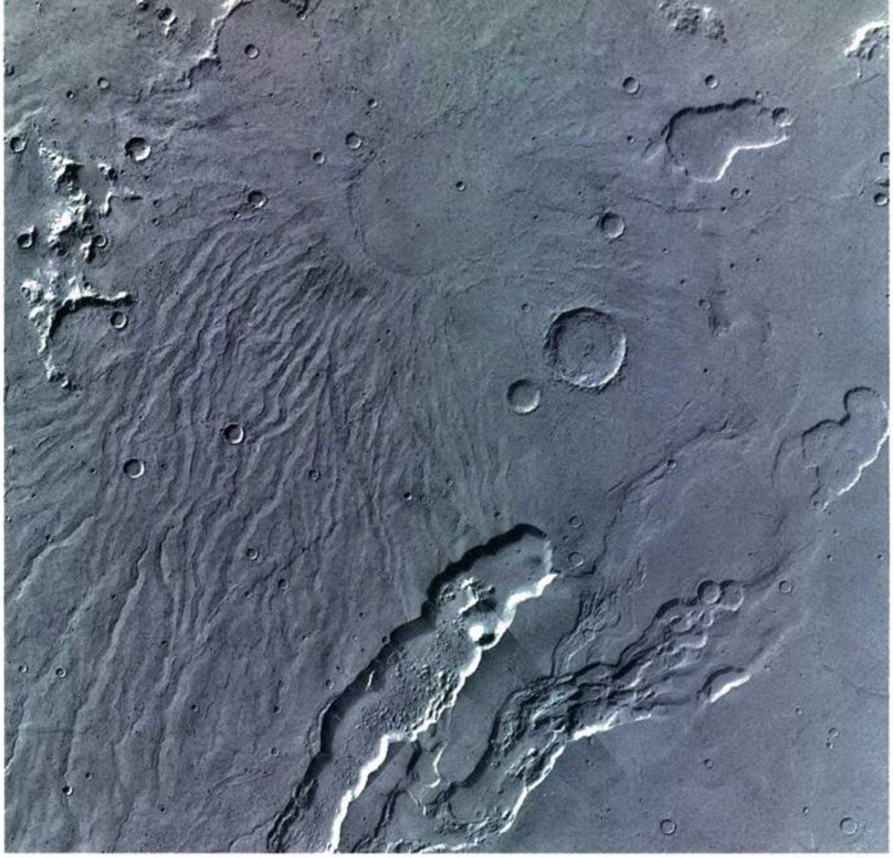


The long canyon system known as Valles Marineris contains several possible dried lake beds, including Hebes Chasma (arrow). Unfortunately, landing a spacecraft to search for life in this rugged terrain is beyond current capabilities. USGS by nearby volcanic sources could create many of the fluvial features seen on the planet's surface.

Because hydrothermal springs naturally fossilize living organisms — and because such springs might still exist today — they would be perfect sites for a fossil search. Unfortunately, a hydrothermal spring typically covers only a small area on the surface, and planetary scientists have not yet firmly identified one on Mars. Until high-resolution images and mineralogical mapping locate such a spring, these potentially exciting targets for sample return missions will remain elusive.

Drilling in the Ice

Any samples returned from an ancient lake bed or hydrothermal spring would be scrutinized by scientists looking for fossils. Obviously, the discovery of unambiguous fossils of life on another planet would be a historic event, overshadowing even last year's identification of possible past life. But such a discovery would still leave many questions unanswered.


NASA/JPL

Bruce Jakosky

Dale Andersen/NASA

Hydrothermal springs in Yellowstone National Park (above left) form fossils as the hot water cools and minerals precipitate. The author examines another spring (above), though this one lies in permafrost in the Canadian Arctic. A possible site to search for life on Mars is Dao Vallis, where a fluvial feature perhaps formed by a similar spring emerges from the side of a volcano (top).

One would be how life on Earth is related to life on Mars. It's quite possible that life originated on one planet and then traveled to the other on a meteorite during the period of heavy bombardment, which ended 3.8 billion years ago. Evidence exists for life on Earth at this time, and viable spores could have journeyed from Earth to Mars or the other way around. If so, life on Mars may have been the same as life on Earth. Alternatively, life on Mars may represent a second, independent genesis of life. To answer this question requires more than fossils — we'll need to examine the body of an actual martian microbe, even if it's dead.

The intact organic remains of a martian organism could still exist at one site on Mars — in the permafrost near the planet's south pole. David Gilichinsky of the Puschino Institute for Soil Sciences in Russia and his colleagues have found that microorganisms in the permafrost of Siberia are still alive after being frozen at –10° C (15° F) for more than 3.5 million years. The southern polar regions of Mars include areas of the ancient cratered terrain that have probably remained frozen at temperatures of –70° C (–95° F) and below throughout the entire history of Mars.

At the lower temperatures of the martian permafrost, organisms would degrade at a much slower rate than in the Siberian permafrost and, if this were the only consideration, we might expect to find living martian microorganisms deep in the frozen ground.

The bland, orange-colored Mars seen from Earth bears scant resemblance to the pockmarked planet revealed by orbiting spacecraft. Nevertheless, the Red Planet can be seen during August as a ruddy point of light low in the southwest about an hour after sunset.

Unfortunately (or fortunately if you think martian microorganisms pose a potential threat), the gradual accumulation of background radiation will have killed the frozen martian bugs. Direct measurements 50 meters (160 feet) down in the Siberian permafrost show that a lethal dose of radiation (about 2 megarads) would accumulate in about 10 million years. That means about 50 percent of the Siberian microorganisms will die after 10 million years underground. This radioactivity arises from trace levels of naturally occurring uranium, thorium, and potassium. Similar levels of these elements exist in the crust of Mars, and as a result any bugs frozen in the martian permafrost would have accumulated hundreds of times the lethal dose. Although the martian permafrost microorganisms would be "dead on revival," they would be intact and scientists would be able to analyze their biochemical and genetic properties. We could tell if they are merely another branch of Earth life, or conversely if we are just another branch of Mars life, or whether life on Mars is fundamentally independent of life on Earth.

If scientists find fossils of clearly biological origin on Mars and thus answer the question of whether life once existed there, their interest will certainly turn to the relationship of that life to our life. Then drilling in the martian permafrost will begin.

Choosing a Site

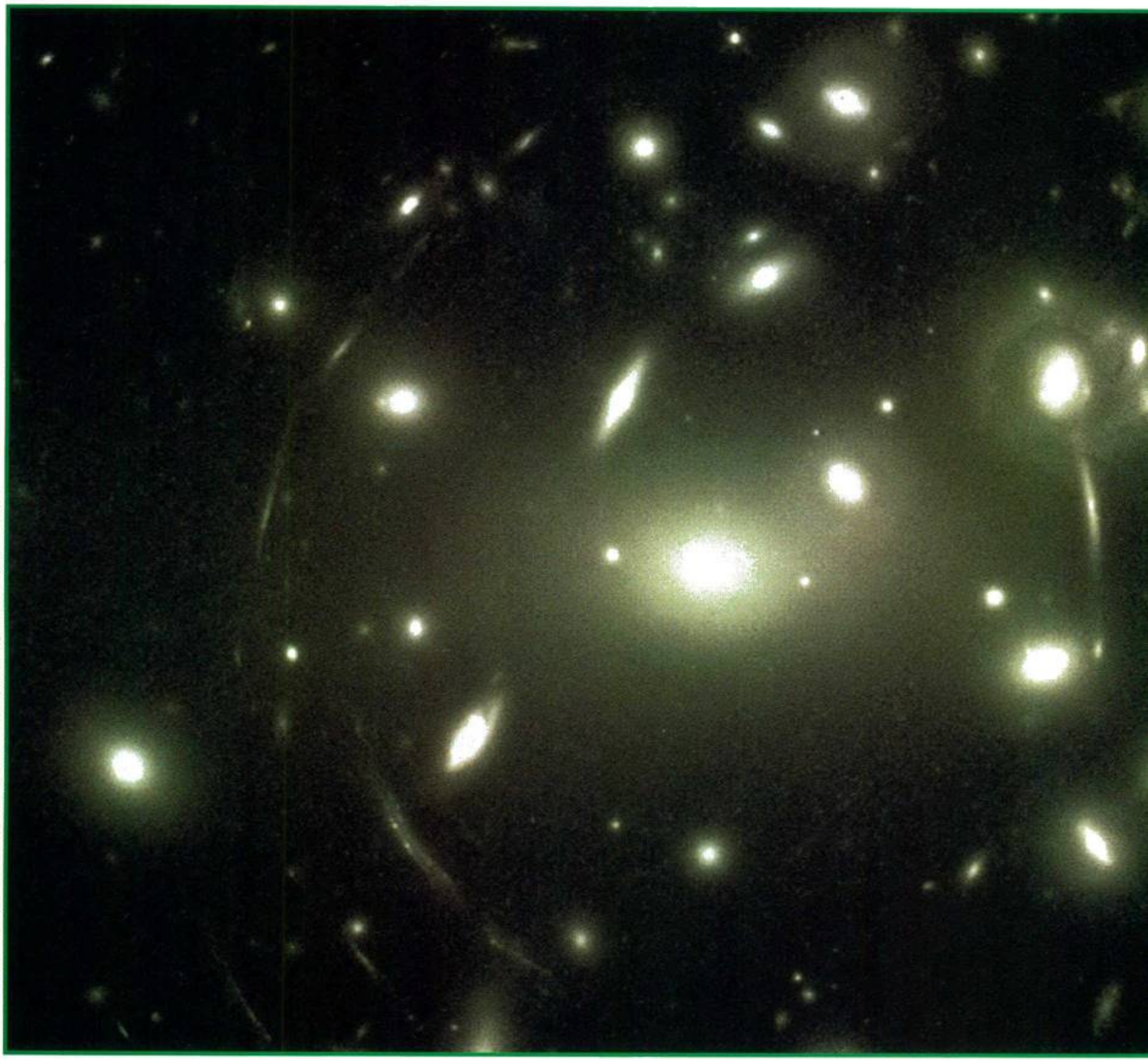
NASA researchers and administrators are seriously discussing a sample return mission that could occur as early as 2005. What kind of site should we visit on the first mission? I think we should rule out going to the ancient cratered terrain because the rocks returned likely will be no different from the martian meteorite already in hand. A better destination would be a site where water once existed. Here an ancient dried lake bed, similar to the ice-covered lakes in the Antarctic dry valleys, provides the best target. A hydrothermal spring would also make an excellent target *if* any of the upcoming missions to Mars can locate one. Although drilling in the permafrost near Mars's south pole could potentially provide the most significant findings, the difficulties of landing near the pole and then drilling probably argue for leaving this to a later mission. Thus I feel an ancient dried lake bed, perhaps the crater Gusev, offers the best target for fossil hunting on the first sample return mission.

Christopher P. McKay is a planetary scientist in the Space Sciences Division at NASA's Ames Research Center in Moffett Field, California. His previous article for Astronomy *was "Did Mars Once Have Martians?" in September 1993.*

The permafrost at Mars's south pole could harbor the actual organic remains of martian life. Drilling there could help scientists decide what relation any martian life has to life on Earth. USGS

Astronomers are taking advantage of one of nature's tricks — grav

GRAVITY'S



Warrick Couch (University of New South Wales), Richard Ellis (Cambridge University), and NASA

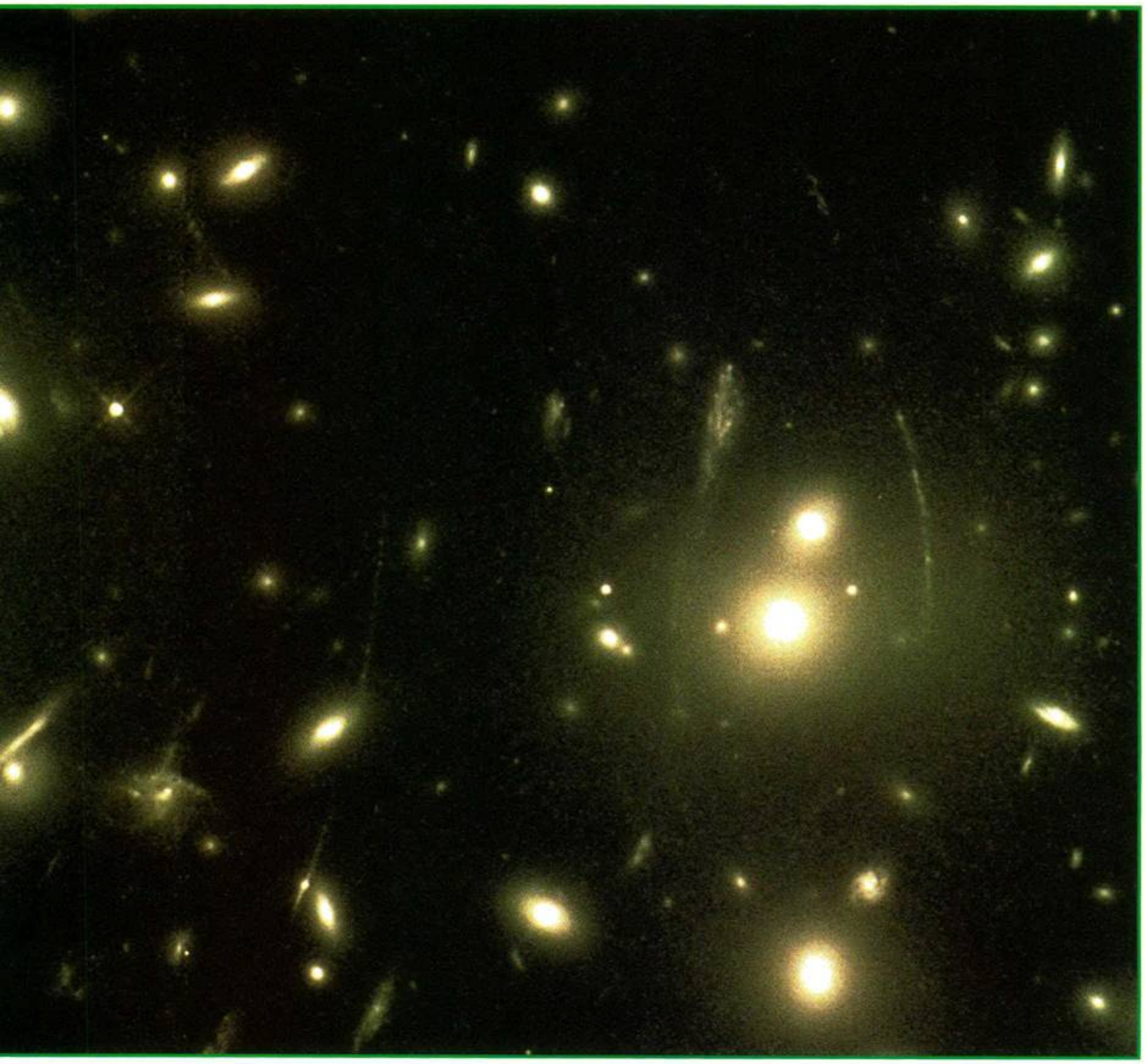
The view is breathtaking. Several bulbous elliptical galaxies sit like contented Buddhas in the middle of Abell 2218, a compact and rich cluster of galaxies situated more than a billion light-years from Earth. A number of bright disks — spiral galaxies most likely — surround them. But there's more. Wispy arcs, 120 in all, encircle the heart of the cluster. The streaks are arranged like the rings of a dartboard. It is one of the universe's most wondrous illusions. The massive cluster is acting like a giant spy glass, only in this case it's the cluster's tremendous gravitational field that is deflecting the light rays passing through it and greatly magnifying the objects that lie far behind Abell 2218. The faint blue arcs are actually the distorted, ghostlike images of distant galaxies that reside some five to ten times farther out than the cluster.

At first, such examples of gravitational lensing were merely *cosmic curiosities*. But over the last decade, gravitational lenses have evolved into invaluable observational tools, applicable to a host

itational lensing — to study the faraway universe.

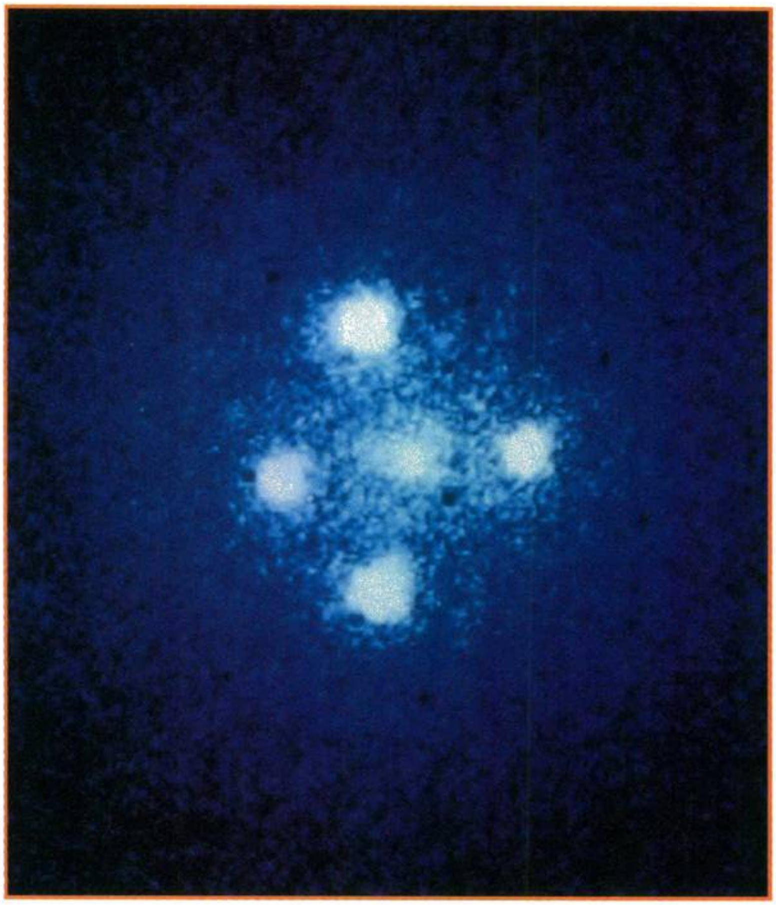
by Marcia Bartusiak

RAINBOW



of key cosmological questions. Astronomers are now using lenses to assess the amount of dark matter in the universe and to pin down the Hubble constant, a measure of the universe's expansion rate (which in turn yields the universe's size and age). And, as witnessed by Abell 2218, lenses can act as telescopic boosters. They take distant galaxies too faint to be seen and bring them into view. In this way, astronomers manage a peek at the universe when it was far younger, a vista difficult to achieve otherwise.

As this Hubble Space Telescope image shows, the massive gravitational clutch of galaxy cluster Abell 2218 acts like a giant zoom lens. The cluster, located 1 to 2 billion light-years away, amplifies and bends the light of more distant galaxies into concentric arcs. Without the lensing effect, the more distant galaxies (which are five to ten times farther than the cluster) would be too faint to be seen even by the most powerful telescopes.



NASA and ESA

The Einstein Cross is named after the physicist who first predicted gravitational lensing. The bright dot in the center is a foreground galaxy roughly 400 million light-years away. The four surrounding spots are actually a single quasar 20 times farther away, whose light has been gravitationally lensed by the foreground galaxy.

International meetings are now regularly held to discuss the observational uses of gravitational lensing, a sign of the emerging importance of the effect. A special website even keeps track of all the key papers being published. The present count numbers more than 1,500. "It's one of the biggest growth fields in astronomy," says Princeton astrophysicist Edwin Turner, who, over nearly two decades, has witnessed the evolution firsthand.

Progress was a long time coming. Science historians, foraging through Einstein's old notes, recently discovered that the great physicist first thought about gravitational lensing in 1912, three years before completing his momentous theory of general relativity, which serves to explain the effect. General relativity tells us that starlight passing by the sun gets bent — deflected — as it follows the curved warp in space-time carved out by the sun's massive gravitational field. The sun, in effect, acts like a lens. When the glass of an optical lens bends light, it allows the object behind it to be magnified and brightened. A gravitational lens acts in the same way, only now it is gravity doing the work, not a curved piece of glass.

Einstein and others discussed the possibility of lensing occurring farther out in space, as light passed by faraway stars. Depending on the orientation of the "lens" to the background object, the object could be magnified or split into multiple images, as if some giant fun-house mirror were at work. But in 1936 Einstein concluded that "there is no great chance of observing this phenomenon" beyond the sun, since the changes were too small to be detectable.

Lenses Galore

Caltech astronomer Fritz Zwicky had no such qualms. He wrote in 1937 that galaxies offered "a much better chance than stars for the observation of gravitational lens effects." Zwicky was correct, but it would take four more decades before his visionary insight was confirmed. Radio astronomers, while checking the visible counterparts to some radio sources in 1979, chanced upon a close pair of blue objects, identical in every way. It turned out to be a mirage; it was actually two images of the same quasar, known as QSO0957+561. An intervening galaxy, acting as a lens, created the cozy pair, soon labeled A and B. Since then, a couple dozen more systems like 0957 have been discovered. Astronomers also found far away galaxies, not just quasars, being lensed, the galaxies' broader shapes smeared into arcs or rings. Gravity lenses, says Durham University astronomer Ian Smail, are "possibly the cleanest visible signature of the curvature of space-time there is. You can just see it in action."

The Hubble Space Telescope has accelerated the discovery process. Its high resolution allows astronomers to extend their searches to fainter (and hence more distant) lenses. For example, during Hubble's Medium Deep Survey, the telescope imaged two distinctive lenses. They are cross-shaped: Each displays four faint blue images in the form of a cross, around a much brighter and reddish elliptical galaxy.

Cross-shaped, or quadruple, lenses are extremely rare. Previously, only two were known from ground-based surveys of the sky. One, discovered in 1985 and dubbed the "Einstein cross," is a quasar lensed by a nearby bright galaxy. The other, the "clover leaf," is also a multiply imaged quasar. The Hubble crosses hold the promise of allowing astronomers to probe the universe even farther out, although there's a drawback: Telescopes with larger mirrors than Hubble's are needed to obtain useful spectra of the lensed objects — spectra are required to measure distances. "For now, the Keck Telescope is the only instrument powerful enough to get their spectra, but, being ground-based, it may not have sufficient image resolution except on rare days," points out Carnegie-Mellon astrophysicist Kavan Ratnatunga, who helped discover the new crosses. Such spectral studies should be hastened, though, when a new generation of space-borne instrumentation comes on line.

Mapping Dark Matter

One of the most successful uses of gravitational lenses has been mapping the distribution of dark matter in the universe. J. Anthony Tyson, an astronomer with Lucent Technologies' Bell Laboratories in Murray Hill, New Jersey, has devoted a large part of his career to this cause. He takes advantage of the fact that faint galaxies in the far universe are uniformly scattered like grains of sand over the celestial sphere. "And we use these galaxies as 'cosmic wallpaper,'" explains Tyson, "to see them get distorted as their light passes by clusters of galaxies closer in." The ways in which the galaxy images get stretched and smeared depends on the amount of mass in the cluster as a whole. So far, his work is confirming that 90 percent of the mass in clusters is indeed hidden and non-luminous. "Clusters are just whitecaps set within a sea of dark matter," says Tyson.

His best example at the moment is a lens known as CL0024+1654, situated some five billion light-years away. This system was first noticed in 1988, although the Hubble Space Telescope later spotted additional arcs. Based on the positions and distortions of the arcs, Tyson and his colleagues could determine the total mass of the lens, the cluster itself. "It's a gigantic mountain of dark matter, with spikes hanging around the galaxies themselves. It's a bumpy and treacherous terrain. Some forms of dark matter can do that; others can't. Things that wouldn't work would be neutrinos." Those ghostly particles are far too energetic to hang around galaxies in such a fashion. What's needed is something more sluggish, such as WIMPs, weakly interacting massive particles hypothesized in the latest physics theories, or MACHOs — herds of dark, Jupiter-like bodies.

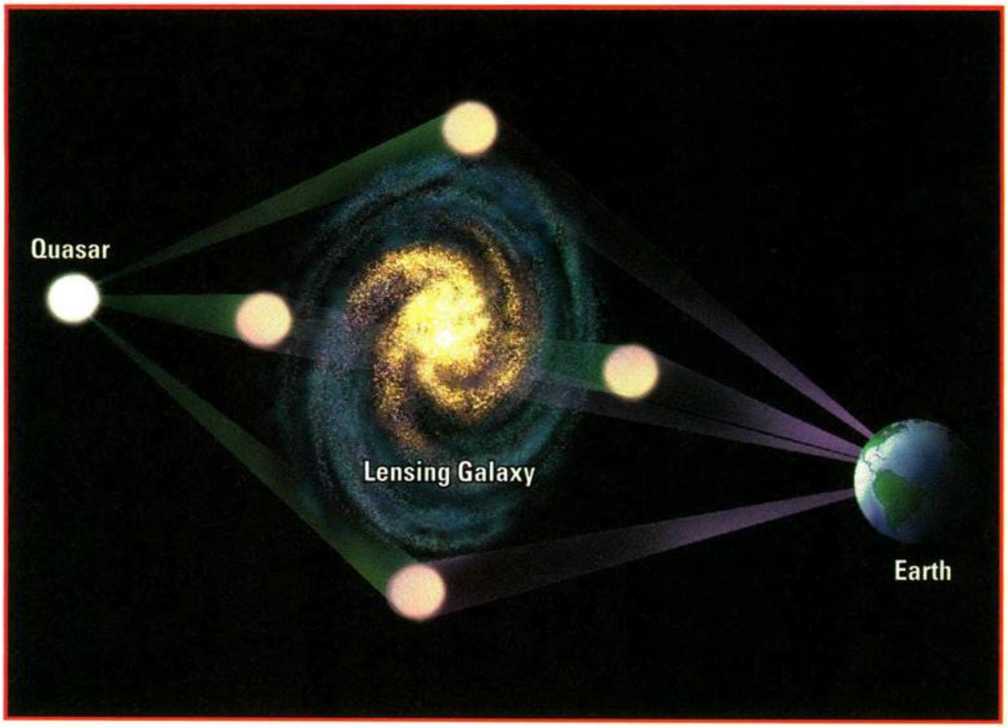
And there's a bonus to such work: With a model of the cluster's size and mass in hand, Tyson and several colleagues were able to reconstruct an undistorted picture of the distant galaxy that 0024+1654 is lensing. The galaxy turns out to be shaped like a ring, a ring that is encrusted with gem-like beads of star formation. It's a glance, perhaps, at a primeval galaxy in the throes of stellar birth. Galaxies such as this tell astronomers what the early universe was like.

Tyson is now concentrating on surveying even larger swaths of sky to see how the dark matter spreads out from cluster to cluster. Is it lumpy? Is it smooth? Answers would provide more clues toward obtaining the proper dark-matter recipe.

Distance Measurements

Ian Smail at Durham, Richard Ellis of Cambridge University, and Jean-Paul Kneib at the Observatoire Midi Pyrenees in France have been using gravitational lensing to estimate a galaxy's redshift, or distance, when the galaxy's spectrum is too faint to be recorded. The more distant a galaxy, the more its light is lengthened — made redder — by the universe's expansion. After obtaining a model of the lens, they assess how the images of distant sources are altered by such a lens. "Basically, the more the galaxy images are distorted — stretched from the galaxy's normal look — the more distant the source," explains Smail. They carried out this procedure on Abell 2218 and determined that the brightest galaxy lensed by the cluster had a redshift between 2.5 and 3.0 (roughly two-thirds of the way back to the Big Bang). A later spectrum found that the true redshift is indeed 2.5. "This was the first time that a redshift, to my knowledge, was predicted from geometry and then confirmed," says Smail. "It was a good day for us." Such a technique, once it's refined, might allow observers to peg distances to objects ten times fainter than currently measured.

It might be argued that the most excitement in this growing field is emanating from those using gravitational lenses to pin down the Hubble constant, the universe's rate of expansion. (For years, the constant has ranged between 50 and 100 kilometers per second per megaparsec, corresponding to an age for the universe between roughly 20 and 10 billion years, respectively; the faster the universe expanded to its current size, the younger it must be.) Astronomers are helped by the fact that quasars often fluctuate in brightness. When the quasar's image is doubled or quadrupled by an



Astronomy: Terri Metzger

intervening cluster or galaxy, the light beams of each image follow slightly different paths, arriving at Earth at different times. The differences in timing, plus a good model of the lens, serves as a tape measure out to the lens. The method itself is complex, but basically, by knowing the different path lengths and the angle of bending, it is possible to obtain a geometric solution, much the way a surveyor on Earth works out distances.

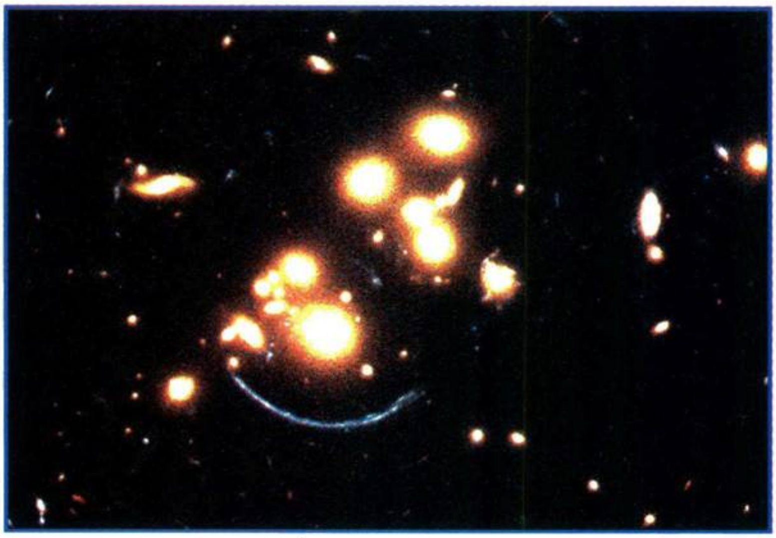
Princeton astrophysicist Turner has been involved in one of the latest tests on the double quasar 0957. Turner and his group first waited for the Apache Point Observatory to open in New Mexico, a state-of-the-art 3.5-meter telescope that allows astronomers to conduct remote observations from their university office computers. That made regular monitoring far easier. "We needed only 10 minutes a night," says Turner. And they looked about every other night for more than a year. "We were lucky," relates Turner. "Within a couple of weeks, the brightness of image A dropped by 15 percent, one of the largest changes observed in that source." About 417 days later, following a longer path, the light of image B dropped, and in the exact same way. From this, the group calculated a Hubble constant of 64, give or take 10 percent. That's a bit lower than more traditional measurements of late. But other gravitational lens groups, in work about to be published, are converging on similar numbers. "Ideally, we want all kinds of techniques to converge on the same answer," cautions Turner.

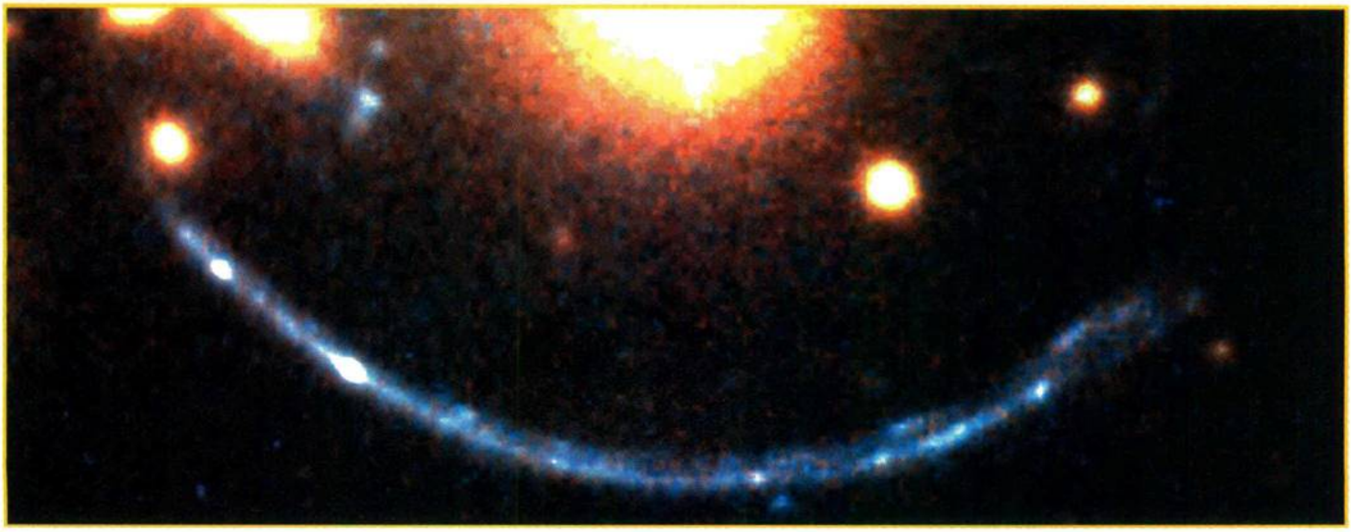
Yet gravitational lensing does have an edge. Other techniques measure distances in multiple steps, one step outward at a time: from Earth to local stars, stars to nearby galaxies, and from galaxies to clusters. One misstep and all other measurements are off. Lensing, on the other hand, allows astronomers to measure the Hubble constant in one fell swoop across the universe.

From the standpoint of backyard observing, gravitationally-lensed objects are extremely faint and challenging. One that can be seen with large amateur scopes is 0957+561A and B, which lies in Ursa Major at 10h1m20.7s, +55°53'56". This object is a 17th-magnitude quasar whose light divides into two images due to an intervening galaxy. Spotting it generally requires a 20-inch or larger scope and a black, moonless night.

Weighing the Universe

Lenses can also test many astrophysical theories, including whether there's an extra "energy" in the cosmos, denoted by a term known as the cosmological constant. Einstein once thought so and incorporated it into his theory of general relativity. But he later took it out. Some cosmologists, though, still like it, because it allows the universe to be a bit older than it looks, so stars don't end up older than the universe. With a cosmological constant, objects are separated by more distance,





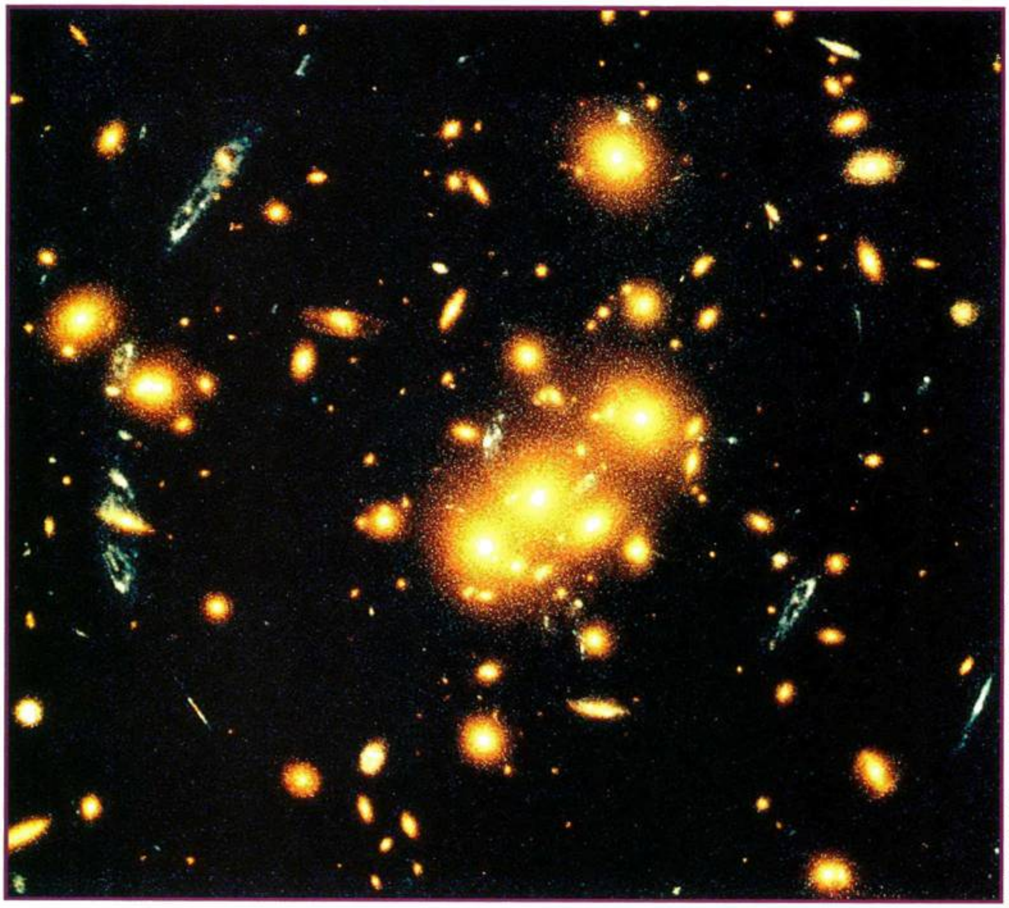
Whether gravitational lensing produces a giant arc or distinct multiple images depends partially upon the exact alignment of the source and lens, but it mostly depends upon the nature of the background object. If it is a point of light, such as a quasar, we will see several distinct images. If it is an extended source, such as a galaxy, the images will usually be merged into a single giant arc.

Bernard Fort (Institut d'Astrophysique de Paris), et al., and NASA/ESA which leads to more lenses per unit volume. But, so far, counts of gravitational lenses seem to rule out a large cosmological constant. If it were large, astronomers would be seeing more gravitational lenses than they do. But a constant hasn't been ruled out entirely; studies continue.

And lenses can be used to "weigh" the universe, to determine whether there's enough hidden mass to cause the universe to collapse someday. Over the last five years, Jeremiah Ostriker and a series of Princeton collaborators have been using supercomputers to build universes filled to the brim with cold dark matter and then predicting how lenses should appear in such universes. In this way, they compare their simulation to the real cosmos and see what matches. Essentially, the more matter there is in the universe, the more chances that lensing can occur. "We numerically shoot rays through this virtual universe to simulate the production of lenses," explains Ostriker. "It's among the biggest numerical simulations ever made. We've recently had one going now [at the Pittsburgh supercomputer center] for about a month." They end up with far too many lenses that are widely separated, ten times more than are seen in the real universe. This may be a strong indicator that the cosmos is fated to expand forever.

Lensing has uses closer to home as well. Einstein would be surprised to learn that lensing by small celestial bodies can indeed be measured right here in the Milky Way's "backyard," thanks to new technologies. The goal is to search for small, dark celestial bodies that might be contributing to the dark matter. A number of programs are being run throughout the world to look at a large stellar population, such as the Large Magellanic Cloud or the galactic bulge, to see if some of the background stars briefly magnify as they are "microlensed" by dark objects passing in front of them.

Awareness of lensing effects is becoming vital, whether an astronomer is a specialist or not. Otherwise, it can lead to some "astronomical bloopers," as Berkeley astronomer James Graham once put it. Take the galaxy FSC 10214+4724. When first discovered in 1991, it was heralded as the most luminous galaxy in the universe. Though bright, it's not as brilliant as previously thought. The Keck Telescope recently revealed that this galaxy is being magnified by a gravitational lens, a foreground galaxy located closer in. Oops, fooled by a gravitational illusion.



Wesley Colley (Princeton University), et al., and NASA

The blue arcs represent the light from a single galaxy located 10 billion light-years away. The galaxy would normally be too faint to be seen, but the lensing effect of the foreground galaxy cluster CL0024+1654, located about 5 billion light-years away, brings it into view. Astronomers can reconstruct the lensed galaxy to find out what galaxies were like in the early universe.

Theorists are even dreaming up new gravitational lens effects. Turner, along with Yun Wang at Princeton, points out that some lensing events could be very extreme, such as tube-like beams of intense radiation coming out of the lens. In a typical globular cluster, for instance, there could be millions of these beams crisscrossing the cluster like celestial spotlights. Each would be strong enough to evaporate dust grains, which might explain the mysterious lack of dust within a globular cluster, says Turner. "I believe gravitational lensing will eventually be seen as one of the major tools for exploring the universe," he says. "If it were a stock, I'd be bullish." ■

Marcia Bartusiak is a Massachusetts-based science writer and adjunct professor of science journalism at Boston University. Her last article for Astronomy, *"What Makes Galaxies Change?" appeared in the January issue.*

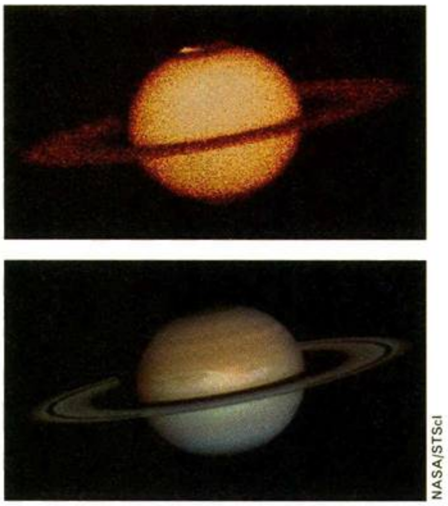
The Man

Robert Williams, director of the Space Telescope Science Institute, brings an unusual blend of drive and serenity to his oversight of the world's greatest observatory.

by Rex A. Graham
portraits by Laura Miller

Behind Hubble

FOUR WEEKS AFTER SPACE-WALKING SHUTTLE Endeavour astronauts repaired the Hubble Space Telescope in December 1993, an ecstatic Maryland Senator Barbara Mikulski waved a Hubble picture of the core of the spiral galaxy M100 at her naysaying colleagues. Today, Mikulski could host a Capitol Hill star party: The orbiting telescope has generated more than 100,000 photos of celestial objects, including a cemetery of dying stars, elephant trunks of dust and hydrogen gas twisting in the Eagle Nebula, jovian storms and aurorae, the rocky rings of Saturn and the colossal supernova smoke rings blown from an exploded star, to list a few. Hubble's pictures do double duty not only as congressional lobbying props, but also as screen savers, T-shirt prints, calendar photos, a background for the "Babylon 5" science fiction TV series and even planet trading cards to be provided soon to schoolchildren.


NASA/STScI

When Williams's institute directed Hubble toward Saturn, it captured an aurora visible in ultraviolet (top) but not visible light.

One of the most electrifying pictures of all, the Hubble Deep Field image began literally as a shot in the dark: the sum of 342 exposures taken with Hubble's Wide Field and Planetary Camera 2 in December 1995 of a black speck of northern sky. Although the Shoemaker-Levy 9 comet impact on Jupiter may have generated a bigger media splash, astronomers still are agog over the Deep Field. Aides to Vice President Al Gore ordered a Deep Field poster from the Space Telescope Science Institute (STScI), which manages the Hubble's science program under contract with NASA. Borrowing a page from Mikulski, Gore plans to use the Deep Field poster to promote scientific research in the next millennium. In an age of cost-cutting and smaller-is-preferred, the $3 billion Hubble has demonstrated that bigger can be better: The telescope attracted 1,298 proposals for observing time during its next annual cycle that began in July, an increase of 30 percent from the previous cycle and more than had been received by any other U.S. telescope or NASA project. Ever.

A driving force behind Hubble's scientific mission, particularly the Deep Field, is astronomer Bob Williams, 56, who took over as director of the STScI a few months before the 1993 repair mission. Like Hubble itself, Williams began his astronomy career with high promise, then was written off as lacking focus. Both have rebounded spectacularly.

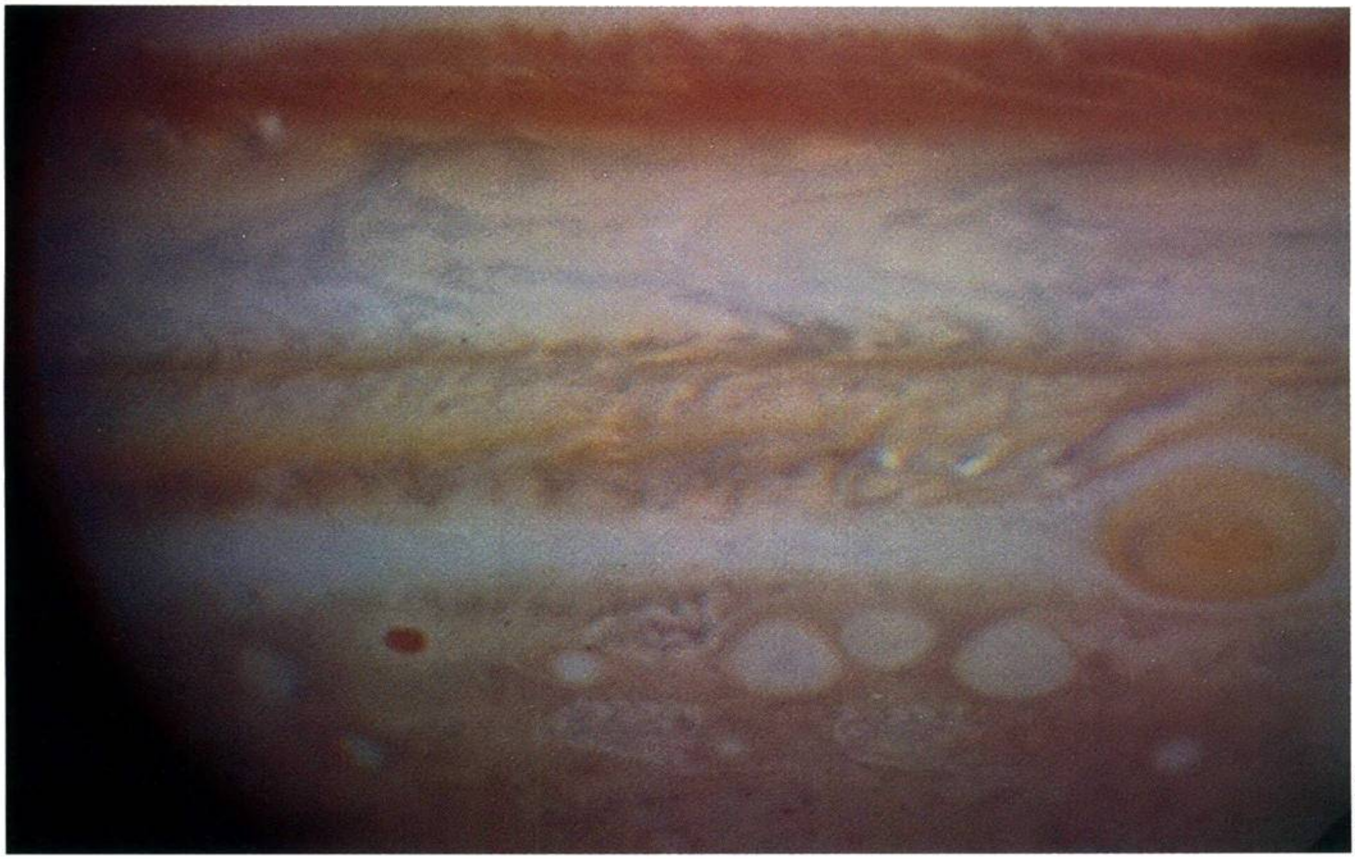
Williams is admired as an articulate champion of astronomy with a penchant for accomplishment. "There is not a devious molecule in his body," says Ray Weymann, an astronomer at the Carnegie Observatories in Pasadena, California, who spent many nights collaborating with Williams in the quiet and darkness of telescope towers.

In graduate school at the University of Wisconsin, Williams excelled as he did as an undergraduate at Berkeley. At Madison, he became an expert on the Crab Nebula, a wispy, cloudlike creature that has been expanding since the supernova of A.D. 1054. He was enthralled with an analysis that he developed, the first of its kind, of the ionizing radiation coming from the nebula's glow. "There are a lot of properties that one can deduce about the nebula from the characteristics of that radiation," says Williams. He agrees that the Hubble pictures of the Crab Nebula as well as the many mysteriously varied shapes of planetary nebulae are "beautiful." But he, like most astronomers, is more rapt when he discusses their spectra: "By looking at the signature of wavelengths of radiation that are emitted or absorbed by the nebula, you can infer things about its chemical composition, size, density, and temperature," Williams says with an almost religious fervor in his voice. "That is what spectroscopy is all about."

What else is Williams all about? To get an inkling, I talked with him for hours, speed-walked to meetings with him for two days, and listened in on his conversations inside the STScI, a brick beehive of science buzzing on a forested corner of the Johns Hopkins University campus in Baltimore.

Williams's handshake was muscular and slightly bony. His slender face could have been mistaken for a minister's — quick to smile and ever relaxed. A fleet-footed athlete since growing up on the ballfields of Ontario, California, Williams has remained thin, almost gaunt, from decades of running 26.2-mile marathons, bicycling, and mountaineering.

His forehead was scarred from two recent surgeries to remove skin cancers that he attributed to decades of sun exposure while running without proper sunblock protection. The cancer might have developed from running the Grand Canyon, rim to rim, three times, the fastest in three hours and 40 minutes: "That was faster than I could drive the car around, going 90 miles an hour at times," says his wife, Elaine Williams, a pediatric psychologist. When he played intramural baseball during graduate school, Williams was known to stretch singles into doubles. At the four-story main STScI building, Williams avoided the building's indolent elevators and bounded up and down its concrete stairways. Williams doesn't saunter, slouch or sit idly during his 16-hour work days.



NASA/STScI

Jupiter's face was speckled with oval clouds when Hubble's Wide Field and Planetary Camera 2 imaged it on February 13, 1995.

Williams traces his first infatuation with astronomy to a 1952 junior high science class. He turned the pages of a school magazine to a picture of Mars. He, like scientists today, was excited by the possibility of life on the planet. He returned to school the following day with his magnifying glass and searched the picture for canals or other signs of extraterrestrial life. He was disappointed, but he knew then he wanted to be an astronomer. "It was straight out of William James's Varieties of Religious Experiences," Williams says. "I had a religious experience and that is what did it. From that day there was obviously something in me that wanted to do it. I would never have changed it."

He soon barraged his parents, who were fundamentalist Baptists, with questions about the origins of life and the universe. They viewed his growing obsession with science in general and astronomy in particular with concern, but they didn't keep him from attending Berkeley or Wisconsin, where he excelled. "Bob derived the photoionization model of gaseous nebulae," says Donald Osterbrock, Williams's doctoral advisor at Wisconsin. "It is still used today."

Williams left Wisconsin in 1965 with a Ph.D. and immediately was hired as an assistant professor at the University of Arizona. Without having endured the purgatory of post-doctoral training, Williams was on the tenure-track at age 24. He piled up publications while studying quasars, the universe's most powerful objects, which emit 100 times more energy than the average galaxy. Arizona awarded Williams tenure before he turned 29.

But Williams eventually became bored with quasars, tenure, and teaching undergraduates he considered too grade-conscious. After 18 years at Arizona, Williams did the unthinkable: He abruptly resigned. He didn't even have a job in sight.

His colleagues at Arizona were stunned.

"I was astounded," Osterbrock recalled.

"People thought I was nuts," Williams says. "I remember one professor at the university who said, 'Bob, what are you doing? I hear talk that you ran off with the baby-sitter!' People thought it was a mid-life crisis, and my marriage was on the rocks — which was hardly the case — Elaine and I have now had our 35th wedding anniversary." Unknown to his colleagues at Arizona, Williams had long been influenced by the writings of the late German-American theologian Paul Tillich. "That's a side of Bob that I don't know very well," says Williams's longtime collaborator, then at Arizona, Weymann. "I was a successful, tenured professor but I just felt I wasn't living near enough to the edge," Williams says. "I wanted to put myself in more of a risky environment because I think I somehow need that, and respond to it. I had no job, no expectations, I just wanted to see what was out there. I wanted to throw myself into the maelstrom."

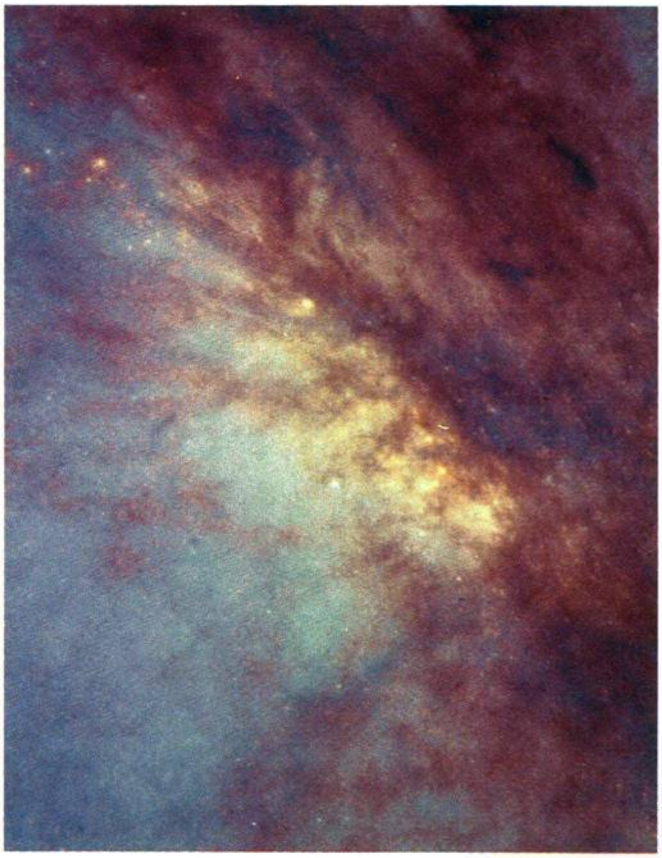
The maelstrom took the form of a one-year fellowship at NASA and a one-year visiting appointment at the European Southern Observatory, before Williams became director of the Cerro Tololo Inter-American Observatory in La Serena, Chile. He remained as director of the observatory for eight years. He took over as director of the STScI when the former head and driving force behind the Hubble project, astronomer Riccardo Giacconi, stepped down in 1993.

Williams's office at the STScI reflects his high-energy pace since he took over. His desk and a nearby table hold stacks of technical monographs, publication reprints, and color prints and slides of galaxies, nebulae, planets, and other objects photographed by Hubble. A poster of the 2,500 or more lumpy, oddly shaped Deep Field galaxies is pinned to his office door. It is the only work-related picture hanging in his office. The image has become a talisman for him and astronomers around the world.

They had hoped for a picture of the early universe ever since NASA's Cosmic Background Explorer satellite discovered tiny ripples — one part in 100,000 — in the microwave background of the universe. The ripples were made roughly one million years after the Big Bang. Did the wrinkles themselves precipitate, roughly 5 billion years later, the galaxies seen in the Deep Field image? "We haven't yet seen what happened during the intervening time, the time between COBE and that picture," Williams says, pointing at the Deep Field image, "and we really need to fill in the gap. That's one of the places where observational astrophysics is going to go in the next several decades."

Williams says Hubble also will be used to probe the dense and dusty centers of distant galaxies. Because of the galaxies' great distances from Earth, astronomers have needed a powerful telescope orbiting above Earth's optically distorting atmosphere to investigate them. "There are really interesting things going on in the centers of galaxies," he says, seated relaxed and upright in a padded chair in his office. (He rarely, if ever, speaks to visitors or STScI staffers from behind his desk, preferring instead to sit with them around a coffee table.) The things that interest Williams inside galaxies include black holes, accretion disks of matter swirling in vortices around super-dense objects, and highly energetic jets, or the "exhaust products" that spew from compact objects, which in some cases are black holes.

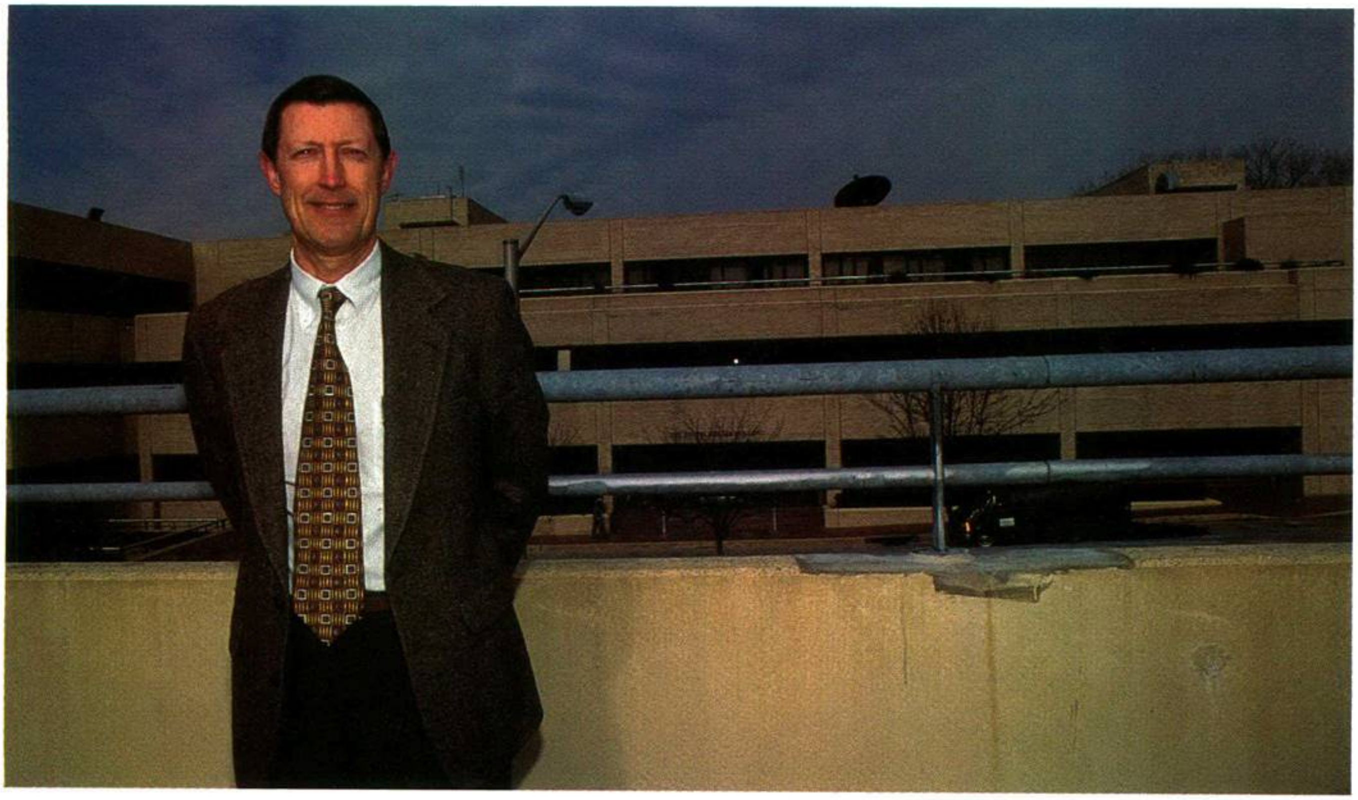
Williams jumped up from his chair, strode to his desk, and held up a Hubble image. "Look," he says, holding a color slide toward the late-afternoon sunlight slanting into his

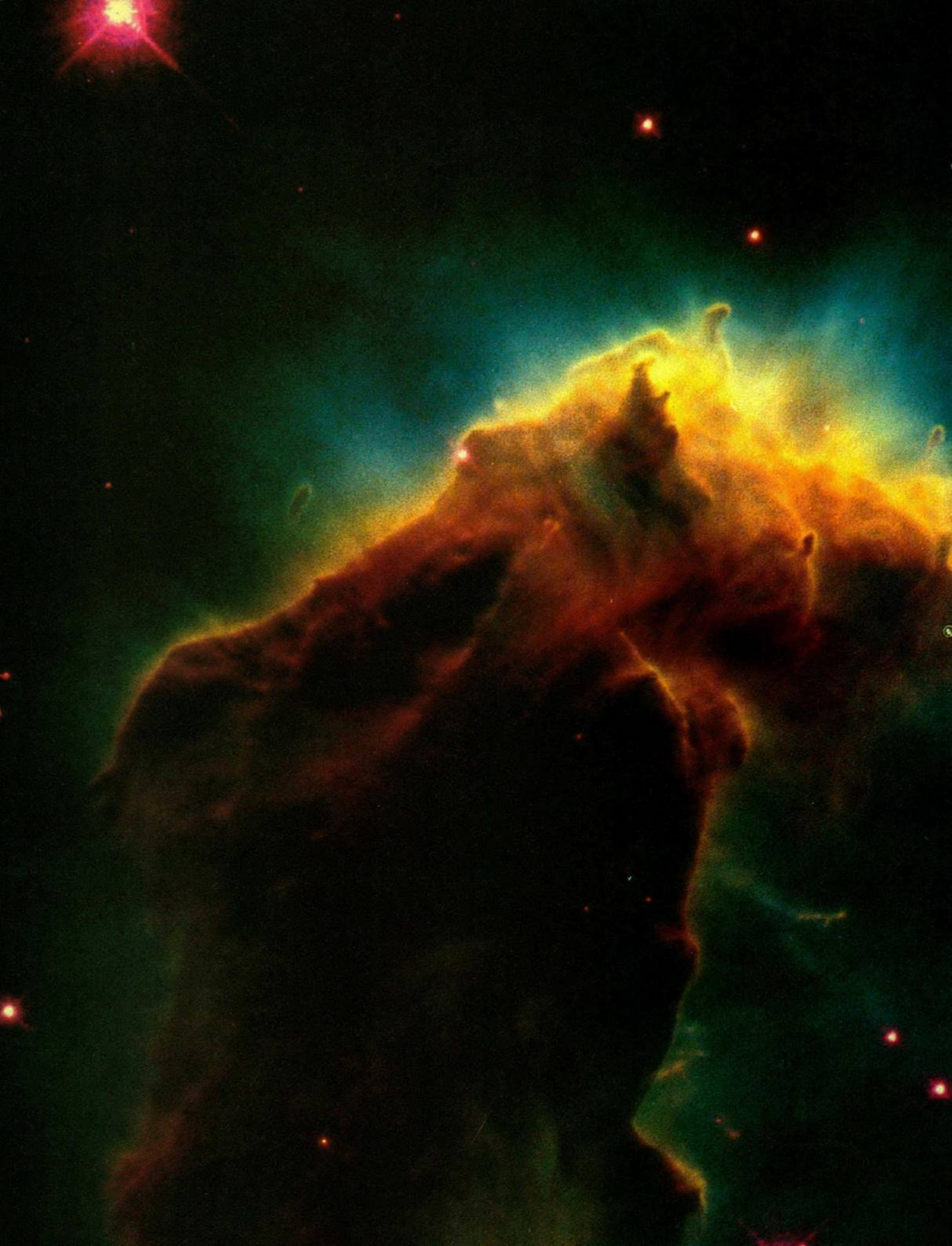


NASA/STScI

The center of the starburst galaxy NGC 253 in Sculptor presents an array of chaos as imaged with Hubble's Wide Field and Planetary Camera 2.

Below: Williams stands in front of the Space Telescope Science Institute in Baltimore, where Hubble's observations stream in each day.





office from a south window. The slide showed a colossal puff of hot plasma extending from a recently formed protostar in Ophiuchus. Williams not only encourages astronomers around the world to conduct follow-up studies of such Hubble discoveries, he also makes it easier for them: Hubble's huge archive of observations can be re-researched, and he made his Deep Field data immediately available via the Internet to anyone who wanted them. "He's extremely anxious that the STScI have the respect of the scientific community," says Weymann. "And he really cares about the science."

Williams poses with his model of the Hubble Space Telescope.

Williams deferred his personal observation time in 1994 so that planetary astronomers could record and study the Shoemaker Levy-9 comet-fragment impacts on Jupiter. The giant planet and its moons have subsequently become a favorite Hubble target. Hubble helped NASA pick the December 1995 entry site for the Galileo probe into Jupiter's atmosphere. No images obtained by an earth-orbiting telescope can compete with those obtained by such space probes.

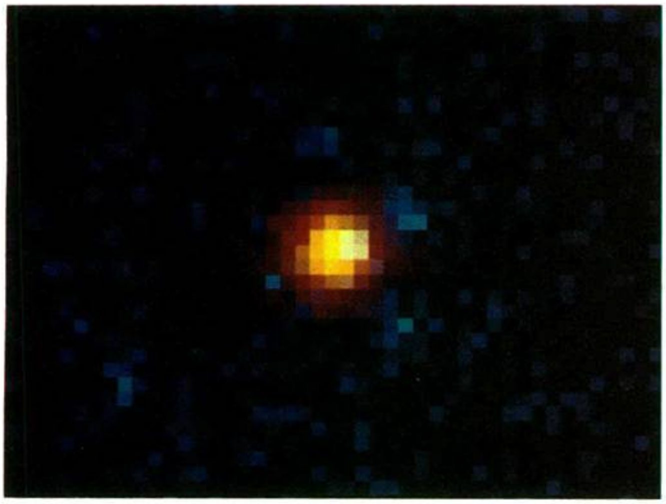
When Williams isn't induced to give up his discretionary time, which amounts to 5 percent of Hubble's schedule, to study unexpected solar system interlopers, he likes to use the time to roll the dice. For example, after the Shoemaker-Levy 9 collision in 1994, he aimed Hubble at the fringes of the galaxy NGC 5128 in Centaurus, where he expected to find prolific star-forming regions. Unfortunately, the dice came up snake eyes. Undaunted, he rolled again in 1995 for the Deep Field observation. There were no guarantees that the 10-day observation, the longest to date made by the orbiting telescope, would reveal much of anything. But this time, the dice came up a lucky seven. "Bob deserves enormous credit for the Deep Field," says Holland Ford, an astronomy professor with a joint appointment at the STScI and Johns Hopkins University. "He was willing to take the risk, and the criticism if it failed."

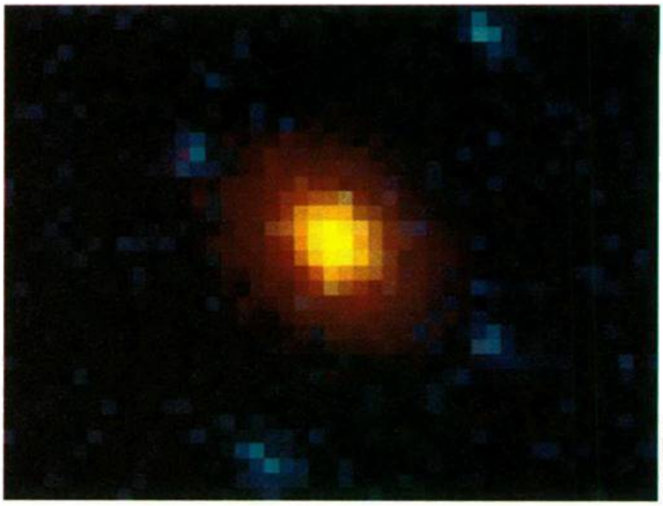
Williams has begun to earmark time on Hubble for observations judged by the members of Hubble's telescope allocation committee (TAC) to be "risky." He often equates the term risky with innovative. He fervently wants astronomers to try observations that haven't been tried before or ones that can't guarantee meaningful scientific results. Ironically, Williams, the consummate risk-taking nonconformist who abhors tenure, has become a Pied Piper for astronomers who not only hope to make significant discoveries, but also gain tenure with the help of Hubble.

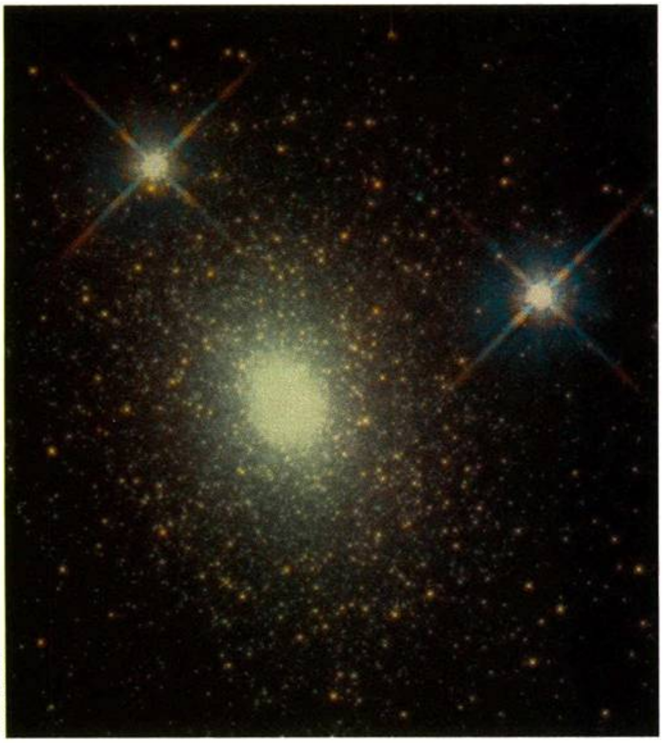
NASA, among the more politically attuned scientific agencies in the federal government, insists that Williams try to make Hubble "user friendly." And a 1996 NASA/Hubble Space Telescope Project evaluation gave the STScI a perfect 100 percent rating in meeting its objectives. But Williams is taking another risky move: this time a political one that could affect his leadership of STScI. He has quietly begun to nudge the STScI away from its recent tendency of providing Hubble time to most astronomers who request some. The change is financially significant: Whoever gets observing time on Hubble also is eligible to receive a piece of the $20 million a year NASA sets aside for so-called data-reduction grants for the telescope's users. That $20 million constitutes almost half of all the salaries paid to U.S. astronomy post-doctoral fellows. The largesse explains why Hubble's popularity among astronomers is so high and also why the telescope's photo album has 100,000 snapshots in it. Williams is influencing more than the ebb and flow of money. He maintains that the trend of providing ever smaller observations and diminishing slices of the $20 million pie to many principal investigators may be counterproductive. Williams stopped short of calling his move a scientific version of welfare reform. But during the first day of my visit to STScI, Williams charged 50 non-

Opposite page: A tower of dust several light-years long marks the heart of the starbirth region known as the Eagle Nebula in Serpens.

Below: Cross-shaped gravitational lenses imaged by Hubble carry the distant light of quasars lensed into fours by a closer galaxy.


NASA/STScI


NASA/STScI


NASA/STScI

Hubble's image of globular G1 resolves into myriad stars — the cluster orbits the Andromeda Galaxy, lying 2.2 million light-years away.

institute astronomers who had volunteered to serve on the Hubble TAC to remember in their deliberations that "the Hubble is not a public works project."

"Officially, the director makes the Hubble allocation, and strictly speaking you are making recommendations to me," Williams told the TAC panel members seated in the STScI's main auditorium. "But I can assure you that it is rare, in fact I cannot think of ever having reversed a TAC recommendation." However, Williams, not the TAC panels, decided that the TAC's operating procedures will inevitably take Hubble time away from small observations of a few Hubble orbits and give that block of time to longer observations.

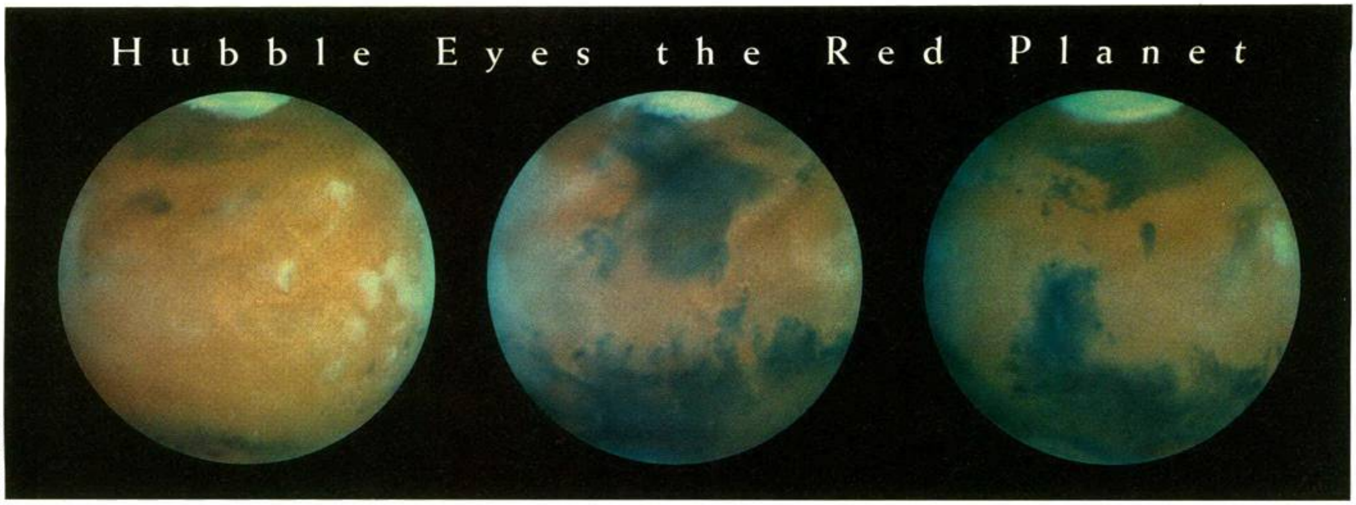
During a break in the TAC meeting, Williams returned to his third-floor office, decorated with, among other artifacts, an Andean wool tapestry and a miniature stained glass rendition of the "Blue Virgin" from France's Chartres cathedral. Williams lunged to a ringing telephone. The caller said the vice president wanted a Deep Field poster as part of a planned speech about the future of American science. Williams added pleasantries and short sentences before a swift good-bye. Next, he swiveled his chair to a computer keyboard behind him and swiftly rat-tat-tatted an e-mail message, a reply to one of dozens waiting to be read. Later that day, one of the messages was from an indignant colleague who was upset that, in his judgment, Williams had equated "small" with "public works." Miffed at himself for not explaining his move and its intended effect to get more interesting science out of Hubble, Williams grumbled, "Oh! That's not what I meant!"

By the beginning of the next century, Williams says 40 percent of Hubble's time will be devoted to medium-sized projects of two to six days, and a quarter of Hubble's schedule could be devoted to about nine large projects, each taking 10 days to two weeks or even longer, per year. Williams concedes that his move may lower the batting average of those applying for Hubble time, but he says the policy also should generate more scientific home runs, "and maximize discovery-space."

Opposition has been restrained, so far. But a critic says Williams's idea will give home-field advantage to the astronomers who are affiliated with big, prestigious ground-based telescopes. "Caltech has the Keck Telescope and they can use it for leverage to get time on the Hubble Space Telescope, thereby concentrating yet more power in the hands of a small number of people," says MIT astronomer Paul Schechter. He says the batting average of all astronomers who have sought National Science Foundation grants already has declined as that federal agency has shifted to larger, but fewer, grant awards. "The NSF has for the last three years not funded my work because of the shift," says Schechter, one of the nation's leading cosmologists. "I haven't got a graduate student."

Caltech astronomers took one look at the Deep Field data on the Internet and pointed the 10-meter Keck Telescope in Hawaii at Williams's new galaxies. Keck's spectrographs were used to measure the Doppler-shift of light from several of the galaxies to longer, redder wavelengths. Other telescope spectrographs also have measured the so-called redshifts of indi-

In February 1995, with Mars at opposition, Hubble imaged the planet's whole surface centered on longitudes 160°, 60°, and 270°.



NASA/STScI

vidual Deep Field galaxies. The results have been stunning: Light left some of the galaxies when the approximately 12-billion-year-old universe was a few billion years old. Cosmologists who had used mathematical models to try to explain how galaxies coalesced from gas now had real data. In just one of what almost certainly will be many groundbreaking follow-up discoveries, astronomers using the Infrared Space Observatory (ISO) recently reported that some of the youngest galaxies in the Deep Field had immense star-formation rates; 10 to 1,000 solar masses per year — compared to the current star-forming rate in our Milky Way Galaxy of just one solar mass per year. The ISO observation and the Deep Field image have possibly caught the first brilliant star-forming flashes of what we call the early universe — a brief period when the elements essential for life, carbon, nitrogen, oxygen, iron, and others, were first being minted. "The attention has shifted: It's been a sea change to study these very high redshift galaxies." says MIT's Schechter. "We didn't know what was out there, and now people are trying to follow up on the Deep Field image and work on it."

When asked to discuss the Deep Field observation, Williams's professorial voice thickens and slows like aged Maryland honey. "I'm going to do it again just because . . . Um . . . I think it has turned out to be . . . an important observation. Ah . . . and to confirm that the first Deep Field was not atypical, for drawing implications of the large-scale structure of the universe: You want to make sure the conclusions are based on a field that is typical and not abnormal in some way." Look for a southern version of the Deep Field image, he says, in late 1997.

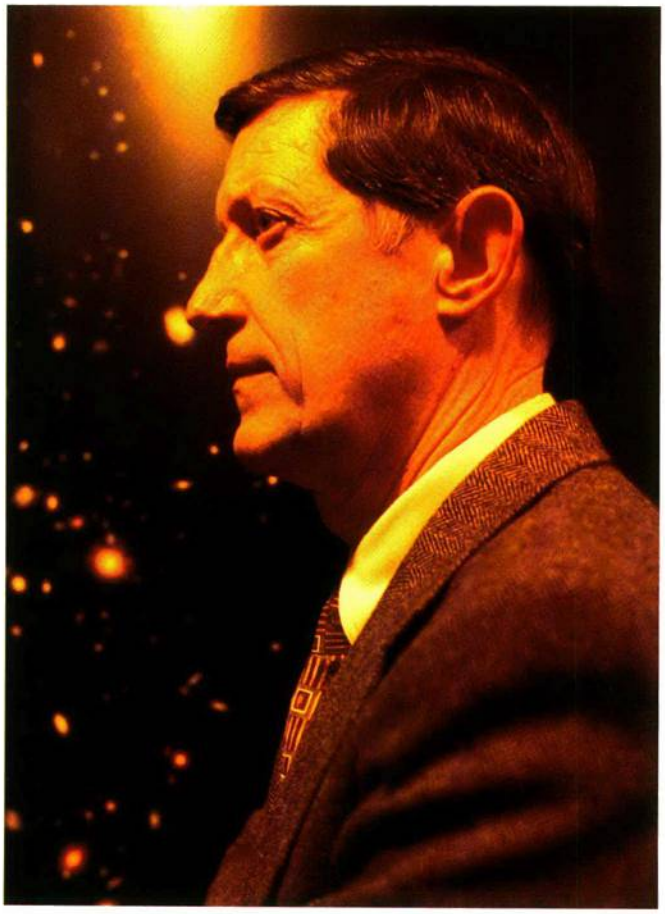
Despite the satisfaction he feels about the Deep Field image, he says astronomers have much to learn about galaxies closer to home. He and others were taken aback with the beautiful 1995 Hubble image of embryonic stars bubbling from the tips of vast "elephant trunks" of dust and hydrogen gas protruding from the Eagle Nebula. The nebula, also called M16, is a nearby star-forming region 7,000 light-years away in the constellation Serpens. The elephantine gas clouds are dense enough to collapse under their own weight to form stars of various sizes. The clarity of the Hubble pictures gave the elephant trunks a three-dimensional look. Young, hot stars forming on the periphery of the hydrogen clouds added to the 3-D effect as they boiled the gas away in an effervescent process called photoevaporation.

Unfortunately, time is not an ally of Hubble. The bombardment of cosmic rays and other radiation is expected to take its toll on the 2.5-ton telescope: Its expected lifetime will expire in 2005. The telescope's mortality was apparent during my visit: The telescope had shut itself down the day before we arrived after its software discovered a glitch. A detector indicated that one of its four reaction wheels, or flywheels, was not spinning at the right speed. The momentum of the four reaction wheels keeps the telescope pointed in the precise directions called for in each of thousands of observations made each year. The software adjusts the rotational speed of each reaction wheel to twirl and stop the school bus-sized telescope at its next target.

As the TAC panel pored over proposals, scientists and engineers with STScI and NASA intently tried to figure out what had gone wrong. The problem was traced to a capacitor, a device that stores electrical energy. The capacitor was fixed, and the Hubble was back on duty in a few days.

Ironically, STScI scientists gathered in Williams's office for a prearranged meeting to discuss the contingency plan that Discovery astronauts would use if problems occurred during their February 1997 servicing mission. In that month astronauts successfully installed a new Near Infrared Camera and Multi Object Spectrometer and a new Space Telescope Imaging Spectrograph. The value of observations with both a camera and a spectrograph was demonstrated in 1996: Astronomers used Hubble and a spectrograph at the Hale telescope on Palomar Mountain in California to discover a brown dwarf. The brown dwarf, called Gliese 229B (GL229B), is a small companion to the cool red star Gliese 229, located 18 light-years from Earth in the constellation Lepus. Brown dwarfs form the same way stars do, by condensing out of a cloud of hydrogen gas, but they are too small to sustain nuclear fusion. Their faint glow is due simply to the heat generated by gravitational contraction. The infrared spectroscopic observations made with the Hale telescope showed that the brown dwarf observed by Hubble had the spectral "fingerprint" of methane that was predicted for a brown dwarf. Hubble could simultaneously picture distant objects, record spectra and determine their redshifts, or ages and distances from Earth. Williams seemed excited about the new instruments. "You sometimes get good gains," he says, "when you take big risks." ▣

Rex A. Graham is a science writer living in Albuquerque, New Mexico.



Williams here is aglow in the light of the Hubble Deep Field Image, one of his crowning achievements.

Jupiter and its family of moons enchant us on August evenings. Morning brings Perseid meteors and an ethereal glow called zodiacal light. By Martin Ratcliffe and Rick Shaffer

IT'S SO BRIGHT YOU CAN'T miss it. Jupiter, the master of our sun's family of nine planets, dominates the nighttime sky this month. You'll find it rising in the east-southeast around sunset, shining like a beacon about a dozen times brighter than Vega, which is currently overhead as twilight fades and the brightest star in summer's night sky. By 10:30 p.m. local time Jupiter's dazzling globe is well clear of the summertime haze that hugs the horizon like a thick blanket.

As you wait for Jupiter to climb higher in the east, Venus vies for equal attention in the west, beckoning to observers from deep within the lingering colors of evening twilight. Although one full magnitude brighter than Jupiter, Venus loses out quickly because it sets only 90 minutes after the sun. During its brief evening appearance, the planet's gibbous phase provides a fine view for telescope users.

Venus's path among the background stars this month takes it south relative to the celestial equator. For viewers in the Northern Hemisphere, this means Venus will not climb very high into the evening sky during the rest of this year. People south of the equator will enjoy a better view.

Mercury opens August below and to the right of Venus, putting on a brief appearance toward the end of its evening apparition. The best chance to identify this apparently intangible globe comes on August 6, when a crescent moon joins Mercury and Venus during evening twilight.

As our planet's spin into night sends both planets out of view, Mars hangs on for another hour or so, ambling along to the northeast of Spica early in August. Its ruddy glow dims to magnitude 1.0, practically identical in brightness to neighboring Spica. This side-by-side pairing of orange Mars with white Spica sets us up to see how color affects our ability to distinguish differences in magnitude. Do they appear

Most skywatchers begin their evening under the stars just as twilight fades to black. Birds settle down, daytime breezes become still, and the air smells laden with dew. One by one, the brighter stars and planets appear. Which evening star will you see first tonight?

Mike Beauchamp

AUGUST 1997

2 Saturn is stationary, 3 p.m. EDT
Mars passes 1.7° north of Spica, 7 p.m. EDT

3 New moon is at 4:14 a.m. EDT
Mercury is at greatest eastern elongation (27°), 8 p.m. EDT

5 The moon passes 1.0° north of Mercury 3 p.m. EDT

6 The moon passes 1.6° south of Venus, 5 a.m. EDT
The moon is at apogee (252,237 miles from Earth), 9:34 a.m. EDT

9 Jupiter is at opposition, 10 a.m. EDT (page 65)
The moon passes 4° north of Mars, 11 a.m. EDT

11 First quarter moon is at 8:42 a.m. EDT

12 Perseid meteor shower peaks (page 67)

16 The moon passes 4° north of Neptune, noon EDT

17 The moon passes 4° north of Uranus, 1 a.m. EDT
The moon passes 4° north of Jupiter, 6 p.m. EDT

18 Full moon is at 6:55 a.m. EDT

19 The moon is at perigee (222,463 miles from Earth), 1:03 a.m. EDT

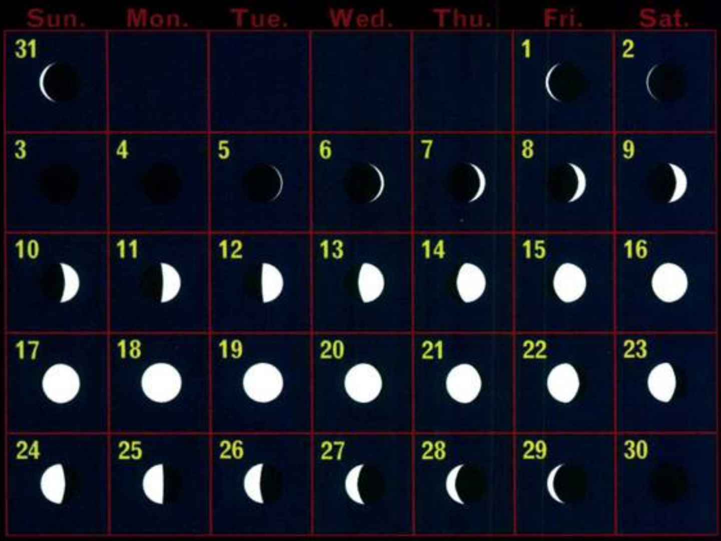
21 The moon passes 0.008° south of Saturn, 10 p.m. EDT

24 Asteroid Fortuna is at opposition, 7 a.m. EDT
Last quarter moon is at 10:23 p.m. EDT

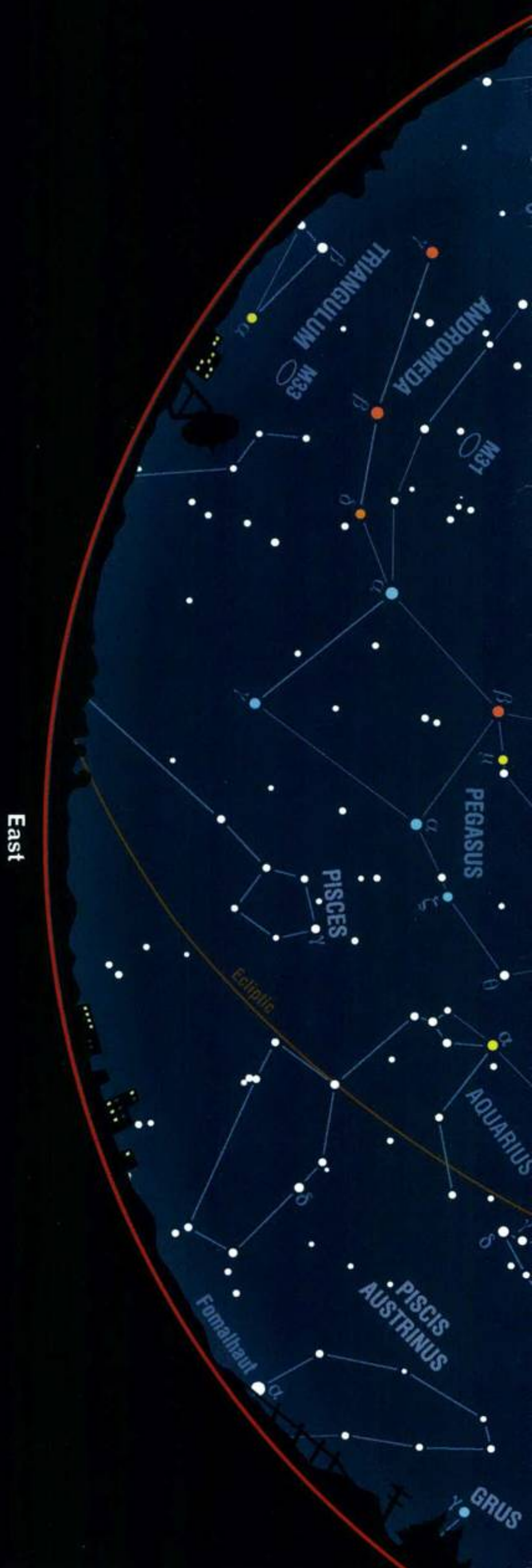
25 The moon passes 0.3° north of Aldebaran, 1 p.m. EDT

29 Asteroid Ceres is at opposition, 11 p.m. EDT (page 65)

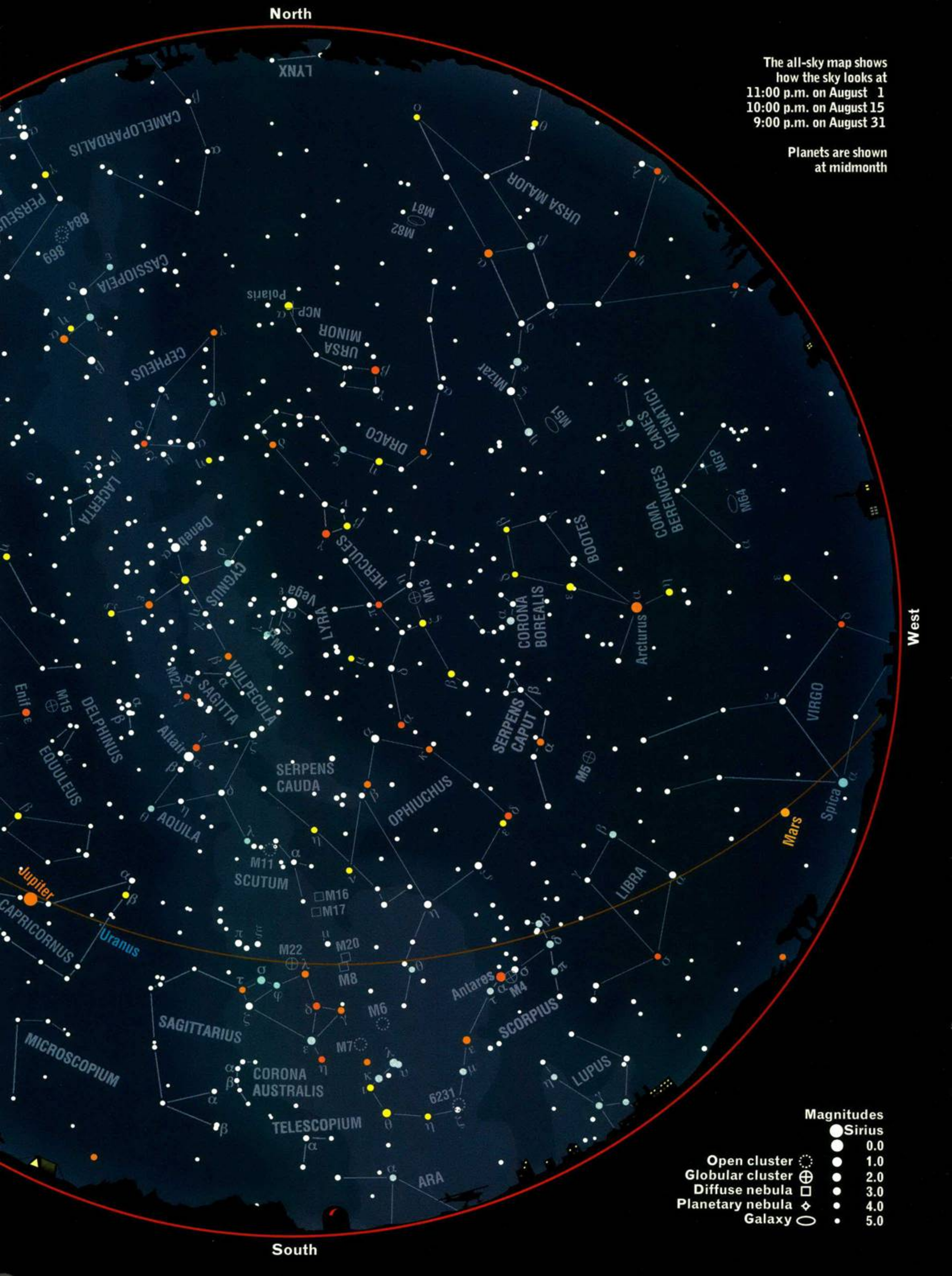
31 Mercury is in inferior conjunction, 10 a.m. EDT



Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30



This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

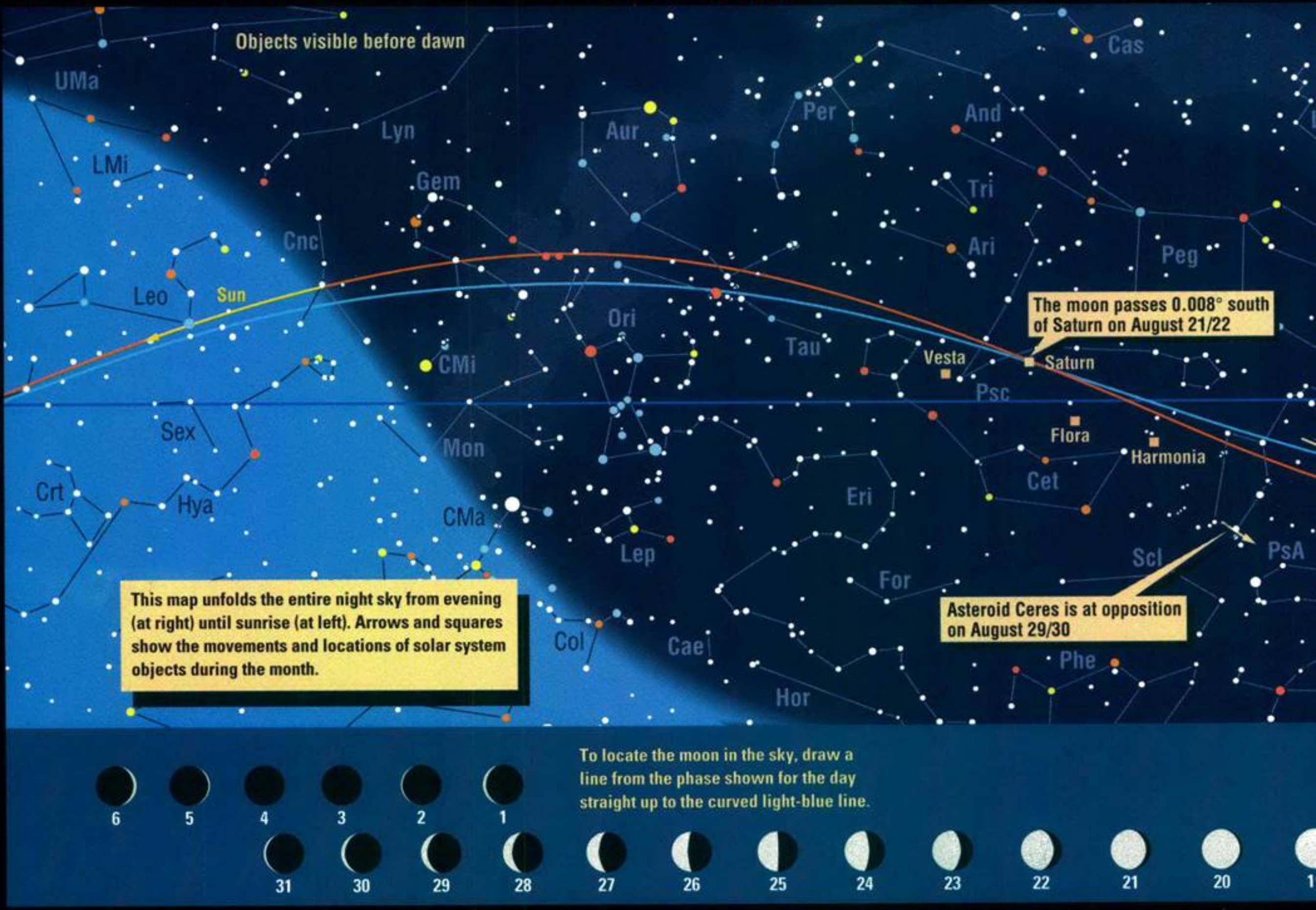


The all-sky map shows
how the sky looks at
11:00 p.m. on August 1
10:00 p.m. on August 15
9:00 p.m. on August 31

Planets are shown
at midmonth

North
South
West
LYNX
CAMELOPARDALIS
PERSEUS
884
869
CASSIOPEIA
Polaris
NCP
URSA MINOR
CEPHEUS
URSA MAJOR
M81
M82
Mizar
M51
DRACO
CANES VENATICI
NGP
COMA BERENICES
M64
LACERTA
Deneb
CYGNUS
HERCULES
M13
BOOTES
Vega
LYRA
M57
CORONA BOREALIS
Arcturus
M27
VULPECULA
SAGITTA
Enif
M15
DELPHINUS
EQUULEUS
Altair
SERPENS CAPUT
VIRGO
M5
SERPENS CAUDA
OPHIUCHUS
AQUILA
Spica
Mars
M11
SCUTUM
LIBRA
Jupiter
CAPRICORNUS
Uranus
M16
M17
M22
M20
M8
Antares
M4
M6
SAGITTARIUS
SCORPIUS
MICROSCOPIUM
M7
CORONA AUSTRALIS
LUPUS
6231
TELESCOPIUM
ARA
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


UMa
LMi
Lyn
Gem
Aur
Per
And
Cas
Tri
Ari
Peg
Cnc
Leo
Sun
Ori
Tau
Vesta
Saturn
Psc
CMi
Sex
Mon
Flora
Harmonia
Cet
Crt
Hya
CMa
Eri
Lep
For
Scl
PsA
Col
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Hor
6
5
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3
2
1
31
30
29
28
27
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24
23
22
21
20

Objects visible before dawn

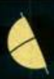
The moon passes 0.008° south of Saturn on August 21/22

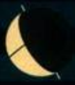
Asteroid Ceres is at opposition on August 29/30

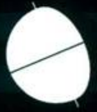
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

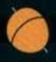
To locate the moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

PLANETS	MERCURY	MERCURY	VENUS	MARS
Date	August 1	August 15	August 15	August 15
Magnitude	0.3	1.0	–4.0	0.9
Angular Size	7.3"	9.2"	13.1"	6.0"
Illumination	52%	28%	80%	89%
Distance (AU) from Earth	0.925	0.728	1.270	1.549
Distance (AU) from Sun	0.463	0.456	0.724	1.503
Right Ascension (2000.0)	10h 29.5m	11h02.7m	11h50.2m	13h52.4m
Declination (2000.0)	8°30'	2°17'	2°01'	–12°11'



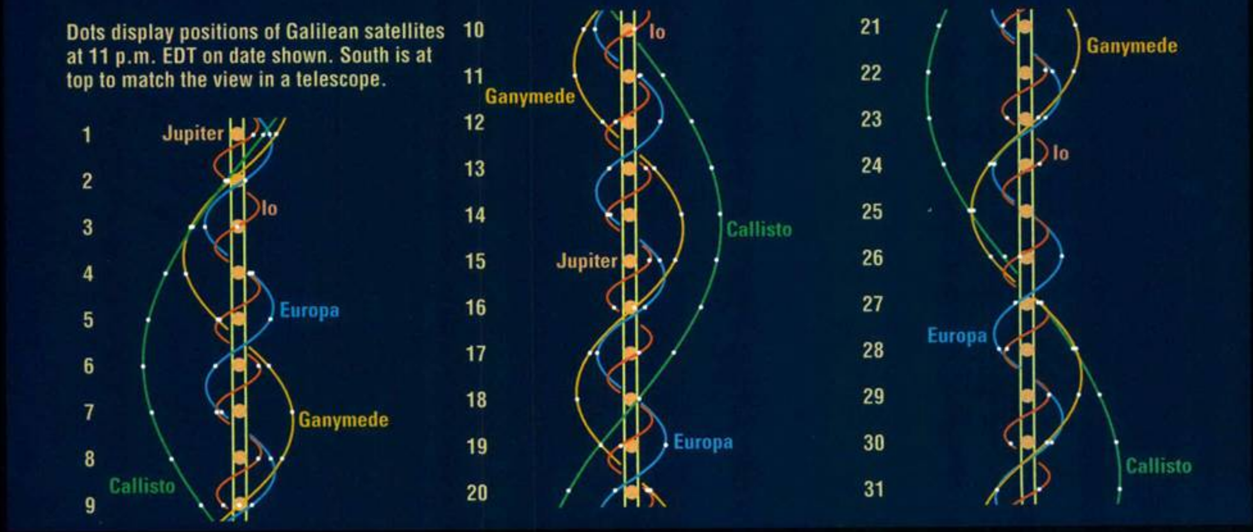


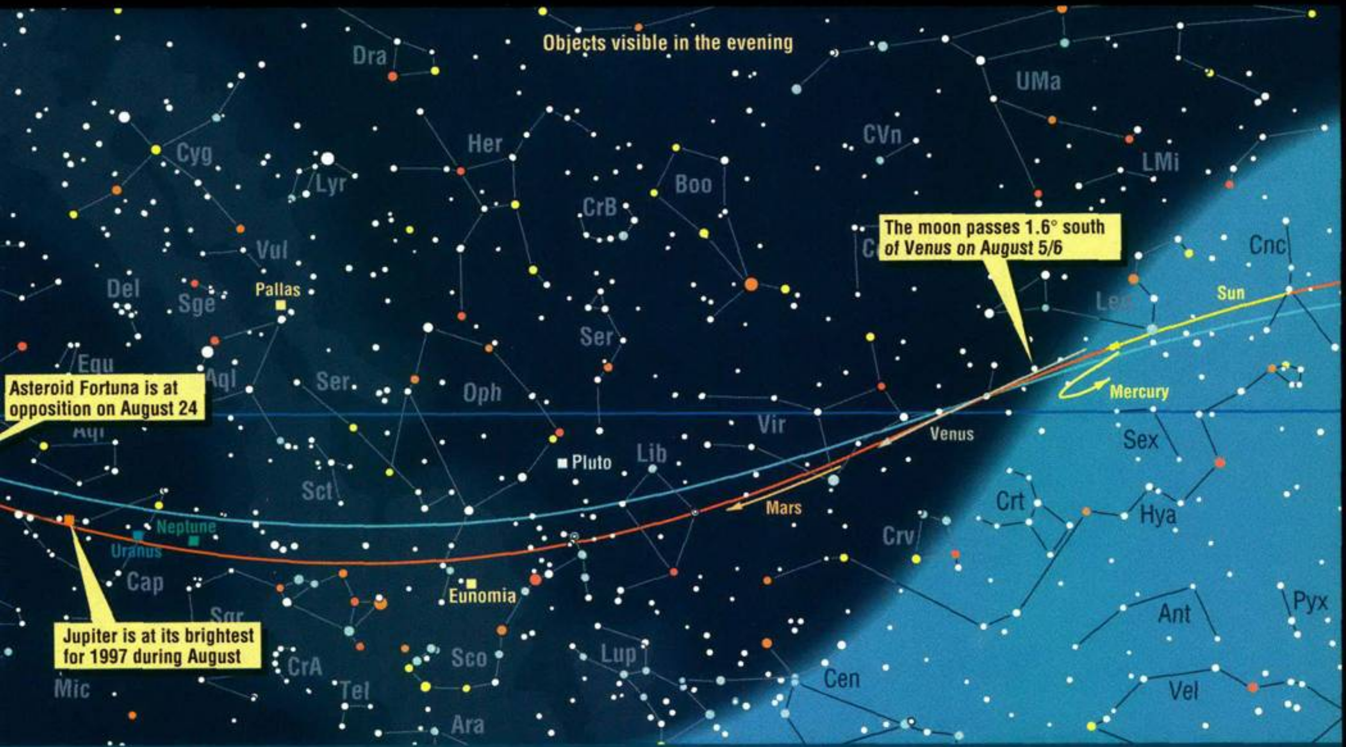




JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 p.m. EDT on date shown. South is at top to match the view in a telescope.

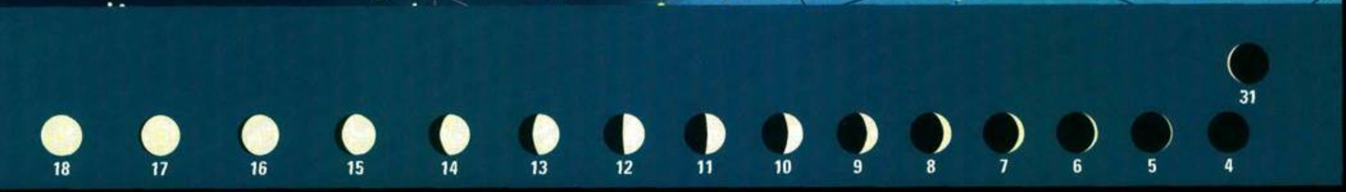



Objects visible in the evening
Dra
UMa
Cyg
Her
CVn
LMi
Lyr
Boo
CrB
Cnc
Vul
Del
Sge
Pallas
Leo
Sun
Ser
Equ
Aql
Ser
Oph
Mercury
Aqr
Vir
Venus
Sex
Pluto
Lib
Sct
Crt
Mars
Hya
Neptune
Crv
Uranus
Cap
Eunomia
Sgr
Ant
Pyx
CrA
Sco
Lup
Cen
Mic
Tel
Vel
Ara

The moon passes 1.6° south of Venus on August 5/6

Asteroid Fortuna is at opposition on August 24

Jupiter is at its brightest for 1997 during August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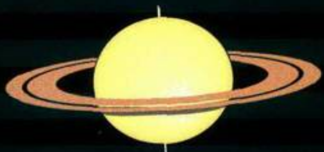
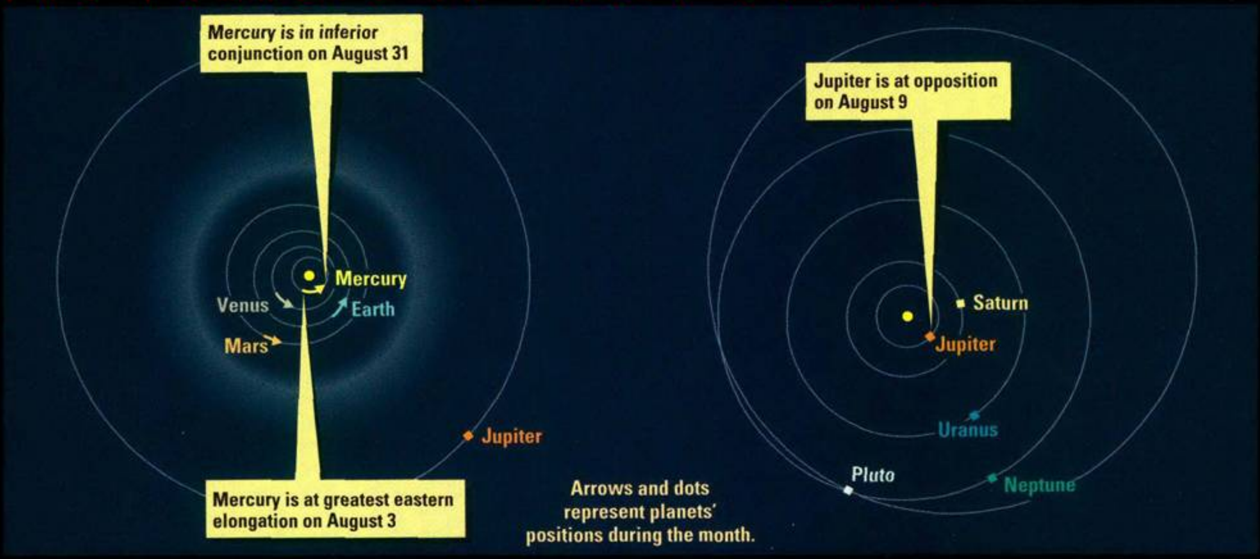


ER	SATURN	URANUS	NEPTUNE	PLUTO
t 15	August 15	August 15	August 15	August 15
3	0.4	5.7	7.9	13.8
"	18.8"	3.7"	2.3"	0.1"
%	100%	100%	100%	100%
3	8.830	18.852	29.224	29.799
1	9.406	19.827	30.149	29.997
3m	1h18.7m	20h34.5m	19h59.8m	16h13.0m
53'	5°29'	–19°23'	–20°10'	–8°28'

THE PLANETS IN THEIR ORBITS


Mercury
Venus
Earth
Mars
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

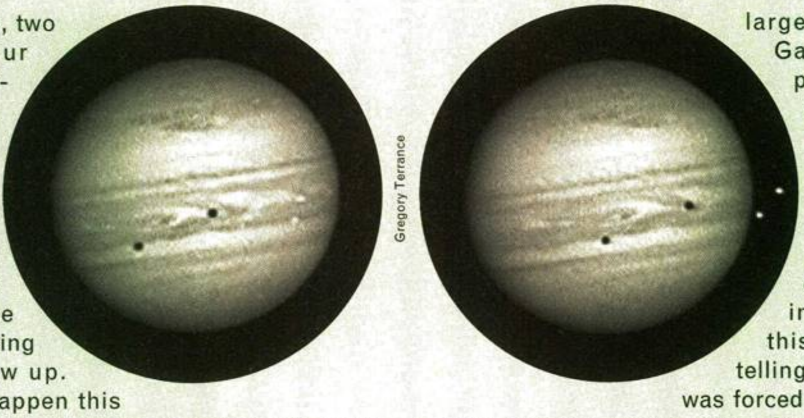
Mercury is in *inferior* conjunction on August 31

Mercury is at greatest eastern elongation on August 3

Arrows and dots represent planets' positions during the month.

Jupiter is at opposition on August 9

FIRST VIEWS: Double Dots on Jupiter



Gregory Terrance

Every now and then, two of Jupiter's four largest satellites transit the planet's face at once. Through a telescope working at moderate power their shadows look like tiny dots of India ink. Under moments of steady seeing, the white dot of a transiting moon will even show up. Three such events happen this month involving the jovian moons Ganymede and Europa: on the 17th at 1:43 a.m. EDT, the 24th at 4:18 a.m. EDT, and the 31st at 6:53 a.m. EDT.

Jupiter's satellites gave humanity its first inkling into how the universe worked. When Galileo Galilei viewed Jupiter with his new telescope in 1610, he immediately discovered that it was accompanied by the four large moons. As he followed their motions night after night, it became apparent to him that these tiny bodies were orbiting the larger one, Jupiter. For Galileo, this was compelling proof that Earth couldn't be the center of the universe; how else could Jupiter be a center around which its satellites orbited? Sure of his conclusion, Galileo informed the Pope of this discovery, and kept telling him until the pontiff was forced to deal with Galileo's heresy publicly. The Catholic Church was only able to extricate itself from the resulting mess a few years ago.

Lesser known is the fact that Danish astronomer Ole Rømer timed the Galilean satellites in 1676 to estimate the speed of light. Rømer noticed that the predicted versus actual times of satellite phenomena differed with Jupiter's distance from Earth. His estimate wasn't very accurate, but it was the first one. It's not clear whether or not he told the Pope.

to be about the same brightness to your eye?

Be sure not to linger too long on Mars when making your comparison. Red-colored objects are known to appear a bit brighter to the dark-adapted eye if watched too long — a manifestation of what's called the Purkinje Effect, a physiological response of the eye to red light. Variable star observers have been aware of this effect for years. Many variables are pulsing red giant stars, like Mira in Cetus. Variable star observers make their estimates of the stars' magnitudes by taking quick glances back and forth between the variable and its comparison stars.

Through a telescope, ruddy Mars's diameter shrinks to 6.0" as its distance from Earth continues to increase. The planet's next good appearance in our skies will be during its opposition in April 1999.

Another reddish nighttime luminary, Arcturus, glows a whole magnitude brighter than the Red Planet as it shepherds Spica and Mars toward a midevening departure in the west. Chaldean astronomers identified Arcturus as Papsukal the Guardian Messenger. Other cultures in Asia called it the Shepherd of the Heavenly Flock.

Both Spica and Arcturus follow the heels of Leo the Lion, now lost in the solar glare. In the past, these two luminaries were referred to as the First and Second Calf of the Lion, respectively. Western culture depicts Arcturus as the Bear Guard for Bootes the Herdsman.

As Arcturus slips from view below the northwest horizon shortly after midnight, the constellation Perseus the Hero rises in the northeast. August is Perseus month, or more precisely, Perseid month, the name given to one of the finest meteor showers of the year. The Perseid meteor shower peaks in activity on August 12, with the best views coming after midnight and after a first quarter moon has set to provide darker skies for meteor-watchers.

Looking for Perseid meteors is easy, especially during the warm nights of summer. Find a comfortable chair or chaise longue. Wrap up in warm clothing so the early morning dampness won't chill you, and then turn your attention to within 45° of due northeast, the direction where Perseus rises into the night sky.

The Perseid shower is one of the sky's more reliable meteor showers, producing a maximum of 100 meteors an hour. Some of these will be bright, especially in the morning hours, which is when our planet's leading edge along its orbit plows directly into the meteor swarm. The shower begins a steady ascent in activity on July 23 and tapers off by August 22.

But it is Jupiter that steals the show during these August nights. Shining brilliantly at magnitude –2.8, it reaches opposition on August 9 in Capricornus the Sea Goat. This places it opposite the sun in our sky and makes it visible all night long.

Because Jupiter completes one rotation on its axis in less than 10 hours, you can view practically the entire planet through a telescope in a single night. The planet's diameter is a whopping 48.7", which makes for a magnificent view at high magnification.

Look for the Great Red Spot, which has gained in prominence and color in the past year. Over time, you'll also glimpse swirls, plumes, dark spots, and white spots in the jovian atmosphere, and the ever-changing arrangement of Jupiter's four major moons, the so-called Galilean satellites, named after Galileo, the astronomer who first spotted them through a telescope.

A Galilean moon is almost always visible at one time or another. But every now and then, one or two of them get occulted by Jupiter or transit the planet's face to blend in against the backdrop of jovian clouds.

This month, however, offers a rare event when all four moons become invisible at once. This happens on August 27 between 5:38 p.m. and 5:56 p.m. Eastern Daylight Time, during daylight for all of North America. Io, Ganymede, and Callisto slip behind Jupiter while Europa transits the planet's face between 4:41 p.m. and 7:32 p.m. EDT. Europa's dark shadow appears on Jupiter's cloudtops between 5:35 p.m. and 8:23 p.m. EDT.

The Jupiter Show draws attention to the rather inconspicuous constellation Capricornus, an ancient star pattern that supposedly shows the head of a goat and the hindquarters of a fish. The Sea Goat's origins go back to the Sumerians and Babylonians. Latin poets referred to the group as Neptuni Proles, or Neptune's offspring.

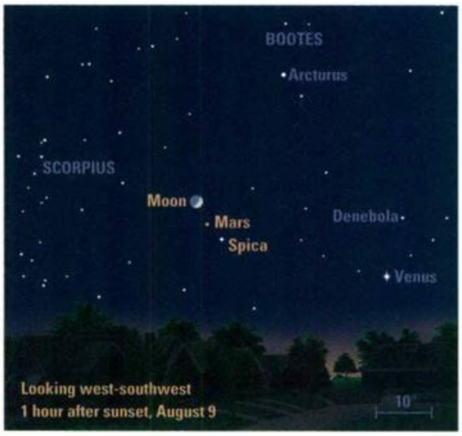
In a curious historical coincidence, the planet Neptune was indeed discovered in 1846 about 5° east of the brightest, easternmost star in Capricornus, Deneb Algedi, which means "the kid's tail" in Arabic. The Sea Goat's westernmost bright star is called Algedi, "the kid," an Arabic derivative for the constellation.

Capricornus is noteworthy for one other reason. The Tropic of Capricorn is the latitude on Earth, 23½°-

The Moon Tours the August Sky

The moon makes one circuit around the sky each month. That's hardly surprising, as our concept of a month is based on one lunar trip around the sky, called a lunation. During August Luna's path takes it close to several interesting celestial objects. This box explores three. The other warrants separate attention.

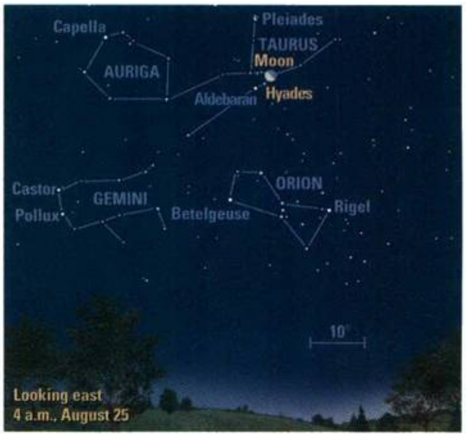
The first notable lunar encounter happens on August 9. Just as twilight ends, you'll find a six-day-old moon 15° above the western horizon. Mars lies 5° below and to the right, shining at magnitude 0.9. That night Mars is 122 million miles away, 510 times farther than the moon. If Mars were the moon's distance from us, it would span almost two lunar diameters.



Looking west-southwest
1 hour after sunset, August 9

Just 4° below and to the right of Mars is Spica. Though the star is 150 light-years distant, it shines at magnitude 1.0 in our skies due to a 40,000° F surface temperature. In comparison, the sun's temperature is a paltry 10,000° F. Note how Spica looks decidedly bluish-white; its vastly higher temperature means that it radiates much more energy toward the blue end of the visible spectrum than does the sun.

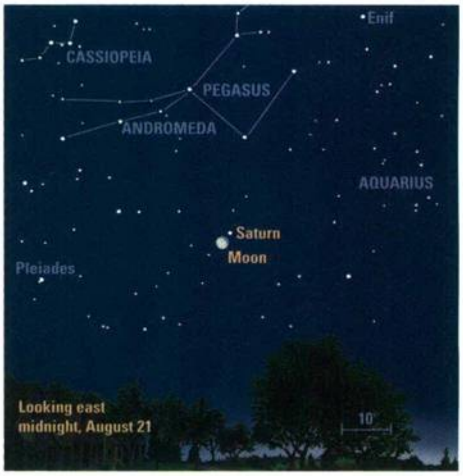
On August 21, the waning gibbous moon finds itself close to Saturn, passing less than half a degree south of the Ringed Planet for most observers in North America. No one needs an excuse to view Saturn, but the light of a nearby moon provides us with a rare opportunity to compare lunar gray-green hues with Saturn's delicate butterscotch tones. Saturn's rings have also opened up a bit after last year's edge-on disappearance, enhancing the view through a telescope.



Looking east
4 a.m., August 25

All illustrations by *Astronomy*: Terry Metzger

After taking in the spectacular rings, shift your gaze east about three ring diameters to Titan, which not only holds title as Saturn's largest moon, but as our solar system's as well. Titan also has the distinction of being the only moon in our solar system with a significant atmosphere. This fall, NASA will launch a spacecraft to explore Titan.



Looking east
midnight, August 21

By August 25, the last quarter moon moves into Taurus, a winter constellation, to occult a number of stars in the V-shaped Hyades star cluster, which makes up the bull's head. Most of the stars in this V are physically bound members of the same open star cluster, except for the brightest apparent member, Aldebaran. It actually lies *many* light-years in front of this huge cluster.

south, where the sun is overhead at the Northern Hemisphere's winter solstice. The sun's actual position at solstice is now in Sagittarius, but during Greek times it used to be in Capricornus. This change is a result of a wobble, or precession, of Earth on its axis, an effect that also changes which stars mark the north celestial pole.

In addition to Jupiter's presence within Capricornus, the 7th planet from the sun, Uranus, lies within the constellation. As August opens, the magnitude 5.7 planet is just three days past opposition and an easy binocular object 4° east of Sigma (σ) Capricorni. Neptune lies farther to the west, in neighboring Sagittarius, glowing somewhat dimmer at magnitude 7.8.

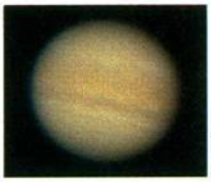
Pluto always offers a challenge if you have an 8-inch scope or larger. It passes between two magnitude 5.6 stars, 16 and 18 Scorpii, toward the middle of August.

Begin your hunt for this planet, discovered more than 60 years ago by the late legendary observer Clyde Tombaugh, by shifting a third of the way east along a line that connects 16 Scorpii to 18 Scorpii. Scientists are hoping that in March 2001, a pair of spacecraft called Pluto Fast Flyby will be launched toward the planet for an encounter in 2013.

If tracking down dim planets doesn't appeal to you, there's always Saturn, a fine sight thanks to a magnificent ring system easily seen in small telescopes. Saturn rises during the late evening hours and remains visible the rest of the night.

This month the Ringed Planet brightens to magnitude 0.4, making it the most luminous object in Pisces the Fish, save for a moon

Jupiter Reaches Opposition



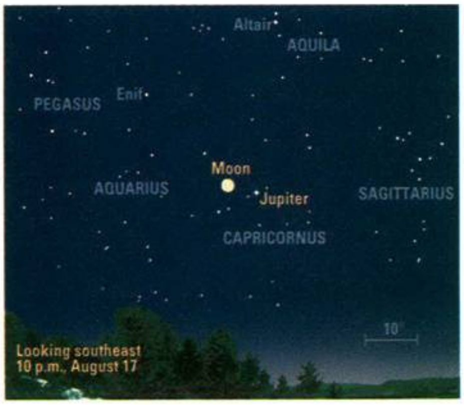
Davis Roles

Jupiter reaches opposition on August 9, when it rises at sunset, culminates in the south at local midnight, and sets as the sun rises. Just over a week later a full moon rises with Jupiter on August 17, though you'll hardly need the lunar presence to find brilliant Jove. It'll be the really bright evening "star" on the other side of the sky from another evening "star," Venus.

If you're just giving Jupiter that first serious look through a telescope this month, you're in for a real treat. Dark belts and lighter zones girdle its huge disk. Observers called these features festoons. You'll also see several white spots rolling along in the dark belts, as well as occasional dark brown spots observers have coined barges.

What we see through a telescope is actually the top of an incredibly thick atmosphere made up mainly of hydrogen gas. Toward the planet's center, where atmospheric pressure is millions of times greater than ours, liquid hydrogen actually takes on a metallic form. Jupiter may even have a rocky core the size of Earth.

But the dominant feature on Jupiter's disk is the Great Red Spot. This long-lived storm (astronomers have known about it for three centuries) wells up from deep within Jupiter's atmosphere and wedges itself between the south equatorial belt and a zone just to the north. Try looking for subtle changes in the Red Spot's border from hour to hour. Observing through a light blue filter enhances the contrast between various features on Jupiter's disk.



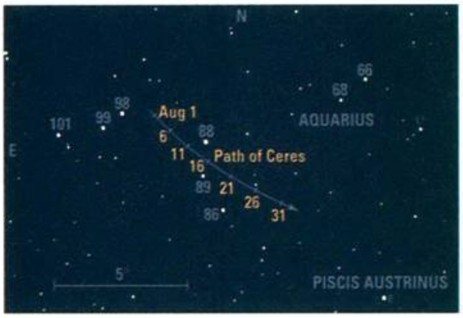
Looking southeast
10 p.m., August 17

Ceres Shines in Aquarius

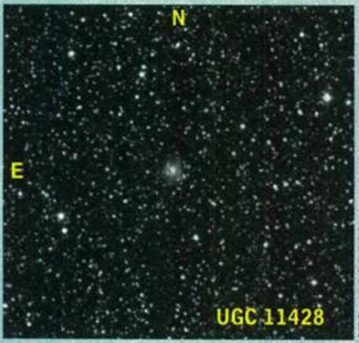
Not only does the solar system's largest planet reach opposition this month, but the solar system's largest known asteroid also lies opposite the sun during August. It's asteroid 1 Ceres, which reaches opposition on August 30. This 623-mile chunk of solar system debris reflects only about 10% of the sunlight that strikes it. Ceres orbits the sun at an average distance of 2.8 AU. That distance, combined with its relatively low albedo, makes Ceres shine at magnitude 7.7 on opposition night, well within the range of 7x50 binoculars.

Ceres is not only the largest known asteroid, it was also the first discovered, on January 1, 1801. Now modern CCD cameras are letting amateurs detect dozens of small asteroids in a single night.

Observing Ceres is just a matter of locating it on the finder chart and then identifying its meanderings through Aquarius. The challenge is not mistaking it for a star. To fully appreciate that you're seeing a world that orbits the sun like our own planet, plot the asteroid's changing position on a star map for the entire month of August. One project for CCD imagers would be to detect Ceres's 9.1-hour rotation during a night.



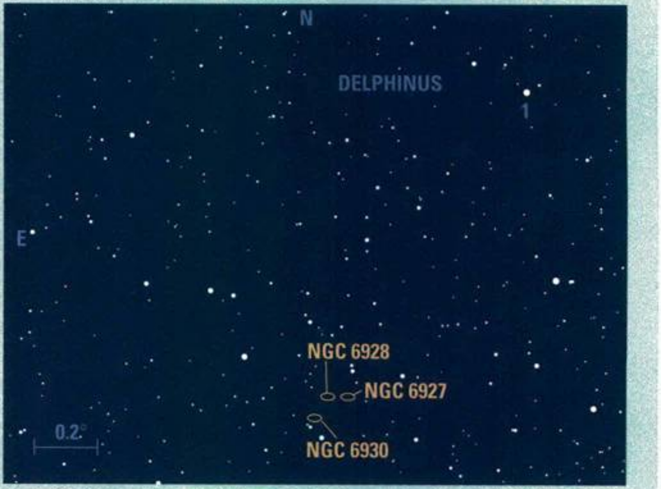
OBSERVER'S CHALLENGE: Galaxies through the Milky Way

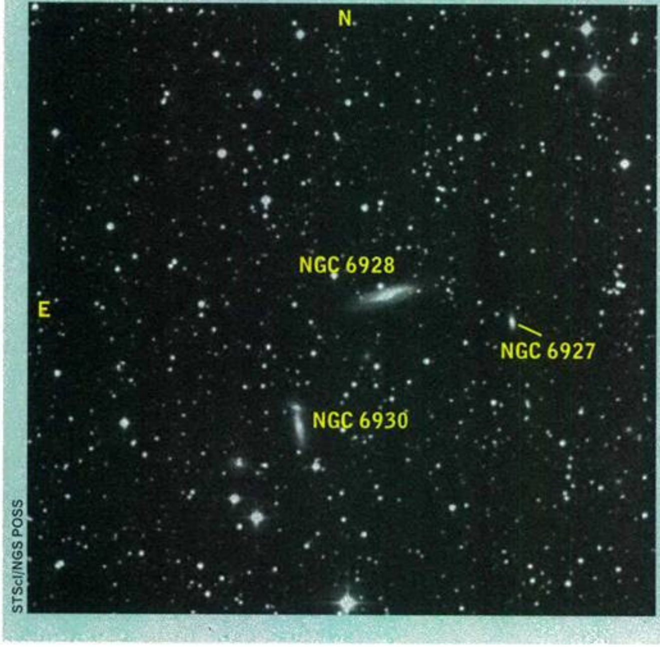


STScI/NGS POSS

If you use a planetarium program on your computer to display the entire sky and "turn-off" every class of object except galaxies, you'll notice a vast smile-shaped void in which no galaxies are plotted. That's because the Milky Way Galaxy, with its gas and dust, blots out our view of the galaxies beyond.

It's this "galactic blotting" that provides for our observing challenge this month. We'll look at a trio of galaxies in the constellation Delphinus and one more in Lyra, galaxies that lie close to the plane of our Milky Way. Were it not for our galaxy and all its dust, these objects might be relatively easy targets. Their squelched light is what creates targets worthy of any advanced observer.





STScI/NGS POSS

Just a bit south of the familiar diamond-shaped asterism of Delphinus, you'll find the trio of NGCs 6928, 6927, and 6930. Edge-on, NGC 6928 shines at magnitude 12.6 and shows hardly more than an elongated shape. At magnitude 14.5, NGC 6927 is much more difficult to detect. The third companion, NGC 6930, is an easier target. It glows at magnitude 13.1 just a bit southwest of NGC 6928. This trio should be a good target for a CCD camera fitted to an 8-inch telescope.

Now swing your attention over to Lyra on the other side of our Milky Way's plane. Take a few minutes to admire the globular cluster M56, and then proceed just over ½° northeast to view 14th-magnitude UGC 11428 at 19h20.4m, 30°50' (2000.0).

You'll need at least a 12.5-inch telescope under a dark, steady sky to comfortably spot the galaxies we've mentioned. Dry conditions have very little water vapor in the air which would scatter light from the galaxies. The need for a dark sky should be fairly obvious; stray light will wash out your view. The requirement that seeing be very steady may seem less obvious at first. Steady seeing ensures that every photon of light gets into the telescope, and not bent somewhere else by atmospheric turbulence. Clean optics also ensure that less light gets scattered.

You may not see these objects the first time out, or even the tenth. Going for such quarry requires a transparent night and clean optics. Even if you're never successful in seeing these objects, you'll be honing your ability to hunt down dim objects in general. Happy (dim) viewing.

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that travels close to the Ringed Planet on August 22. Observers in central Africa see the moon occult, or cover, Saturn on this night. North American observers have just one more month to wait for their turn at seeing a similar event.

By 3 a.m. local time Saturn lies pretty close to its highest point in the sky, approaching due south. At about the same time, you might notice what at first passes for dawn in the east. Look again — true dawn is at least an hour away. What you are really seeing is zodiacal light, sunlight reflecting off dust particles in the plane of our solar system. Its wedged-shaped glow aligns with the ecliptic and is limited to Gemini and Taurus. August and September are perfect times to see this ethereal glow in the early morning. The best viewing opportunities occur early in the month under a dark, moonless sky.

Later in August, the waning moon passes through Taurus, and on the morning of August 25, closes in on

Aldebaran. It will occult Aldebaran, an event best seen during daylight by those on the west coast of the United States and in Hawaii. For Portland, Oregon, the occultation happens at 10:03 a.m. PDT. Farther down the coast, San Francisco sees the bull's eye wink out at 10 a.m.; Los Angeles and San Diego observers witness disappearance 8 minutes and 11 minutes after the hour, respectively. Reappearance occurs 53 minutes later in Portland, and an hour and 14 minutes later in San Francisco, Los Angeles, and San Diego, California.

Meanwhile in Hawaii, Aldebaran gets covered for Honolulu at 4:52 a.m. in the dawn sky and reappears some 68 minutes later after the sun rises.

For observers in the east and midwest, the last quarter moon lies low in the west at occultation time, which would make spotting Aldebaran through the early-afternoon horizon haze rather difficult.

The best way to witness this daylight event is to first center Aldebaran in a polar-aligned telescope that's tracking with the sky, with the help of an electric drive. Do this in the predawn darkness or as twilight gathers in the morning sky.

That failing, try scanning along the moon's lit limb through the telescope at medium power in the minutes leading up to the occultation. Aldebaran should look like a point of ruddy light twinkling against the blue, daytime sky.

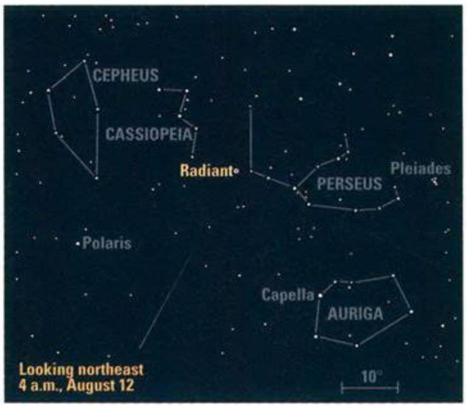
Martin Ratcliffe directs the Henry Buhl, Jr. Planetarium in Pittsburgh, Pennsylvania. Rick Shaffer is a science writer living in Sedona, Arizona.

The Showers of August

The Perseid meteor shower isn't really the best shower of the year. That honor belongs to the Geminids. But the Perseids do grace the warmest month of the year, hence they tend to be more widely observed.

This year the Perseids peak on the night of August 12/13, with meteors trickling in from July 23 to August 22. Their source is periodic Comet Swift-Tuttle, which last visited our neighborhood of the solar system in 1993. As the comet makes trip after trip into the sun's vicinity, dust and gravel frozen in the comet's nucleus gets released and spreads along its orbit. Each August, Earth runs into some of those grains of dust, which get incinerated in our upper atmosphere. The resulting meteors seem to radiate from the constellation Perseus. Forty to 80 of them streak across the sky each hour at the shower's peak.

This year, light from a gibbous moon might interfere with our view of the shower; the glare only gets worse with each night past the 12th. However, because many Perseids are bright, we'll certainly see our share.



Looking northeast
4 a.m., August 12

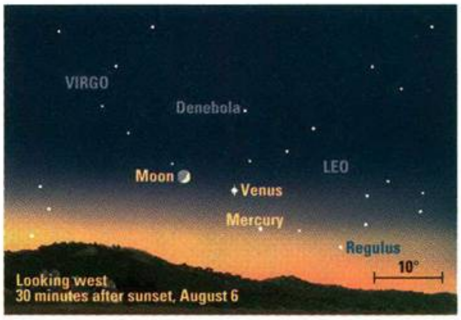
Face northeast, where Perseus is rising. Rest your gaze about 45° above the horizon early in the evening, moving it toward the zenith as the hours pass. Activity picks up as dawn approaches, for it's the morning side of our planet that plows headlong into the swarm.

Planetary Huddle in the Evening

If you know a young astronomer who enjoys viewing the sky, circle August 6 on your calendar. That's when the moon, Venus, and Mercury all huddle within 15° of one another after sunset. Half an hour after sundown, look for a 3-day-old moon low in the western sky, along with Venus 8° below and to the right and Mercury another 6° below and to the right of Venus.

Go for Mercury first, as it's only a little more than 4° above the horizon. Even though this planet reached greatest elongation from the sun just three days before, the angle the ecliptic makes with the western horizon this time of year is so shallow that Mercury's solar elongation doesn't translate into much altitude.

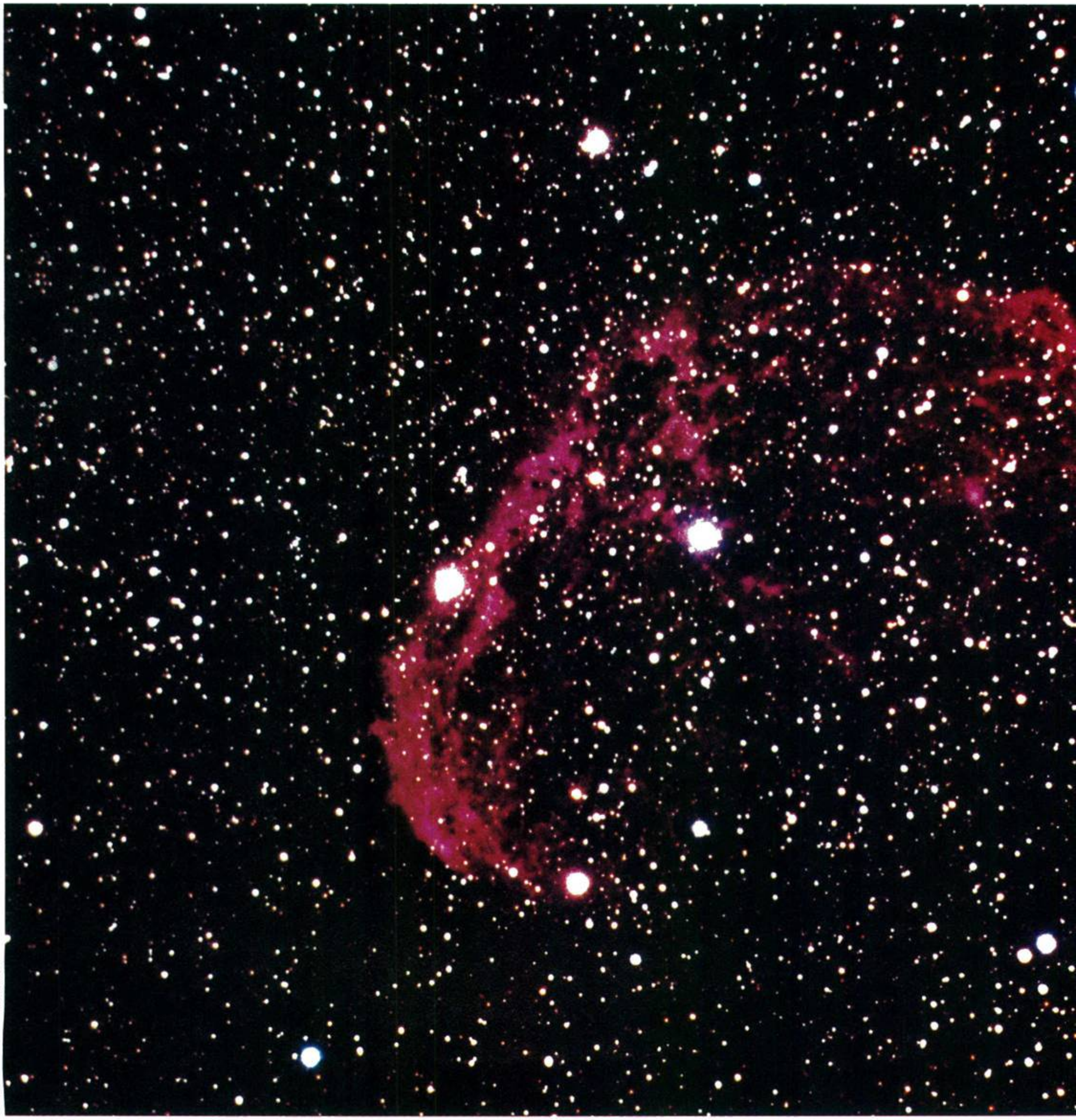
As you view Mercury through a telescope, note a quarter phase that will shrink as the planet closes in on an August 31 pass between Earth and the sun, called an inferior conjunction. Now hop up to Venus to glimpse its white gibbous phase. This brilliant evening "star" emerged from its passage behind the sun last April, and is about halfway toward its inferior conjunction with the sun due to take place in the early part of 1998.



Looking west
30 minutes after sunset, August 6

Now take a look at the planet orbit diagram printed on this month's centerfold. Factor in what you've just seen through the telescope with what the diagram shows for each planet's position. Why are the phases of Mercury and Venus different from that of the moon? Think of an arrangement that lets the moon show a slender crescent phase while Mercury and Venus show fatter phases.

Summer's Magni



George Greaney and Mike Newton

ficent Swan Song

Cygnus the Swan holds a treasure trove of beautiful sights: double stars, open clusters, planetary nebulae, and a gorgeous supernova remnant.

by Alan Goldstein

Of the late-summer constellations, Cygnus the Swan is probably my favorite. The constellation, also known as the Northern Cross, contains a sampling of virtually every form of deep-sky object imaginable: rich star fields, an endless variety of nebulosity, dark clouds, double stars, and yes, even a galaxy or two thrown in for good measure.

Cygnus lies in the galactic plane, which is laden with dust and stars. Because of this fact, Cygnus boasts a great star cloud. This star cloud is the brightest portion of the Milky Way for Northern Hemisphere observers. It would be even larger and brighter if not for the Great Rift, a cloud of opaque dust that blots out more distant stars like a velvety celestial blanket. The rift stretches from the tail of the Swan, near the 1st-magnitude star Deneb (meaning "tail" in Arabic), southwest into Ophiuchus, cutting a swath about 45° across the sky. Both the Cygnus star cloud and the Great Rift are two of the easiest deep-sky objects to observe. They are the proverbial celestial "forests" so often overlooked by observers seeking the various species of "trees" — individual deep-sky objects.

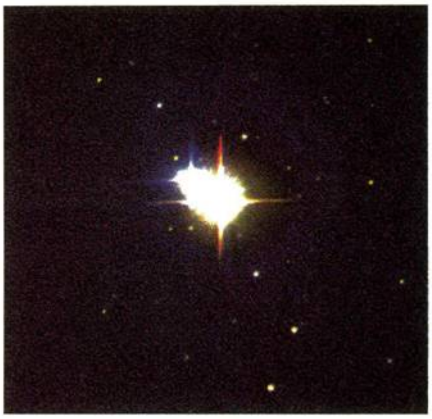
Double Stars

Like most constellations dominated by the Milky Way, Cygnus is rich in double and multiple stars. **Albireo** (Beta [β] Cygni) is the premier double star in the northern sky. Consistently rated as a favorite by sky gazers, it is bright, colorful, and visible in small telescopes at the base of the Northern Cross. The brighter 3rd-magnitude component is yellow, the companion a 5th-magnitude contrasting blue. For those who believe that celestial objects lack color, Albireo proves otherwise. The pair lies about 250 light-years away. Both stars are much larger and more luminous than the sun and are separated by a rather large distance, 3,000 astronomical units. The brighter of the pair is actually a double star itself, although its two stars are too close to be resolved even in large telescopes.

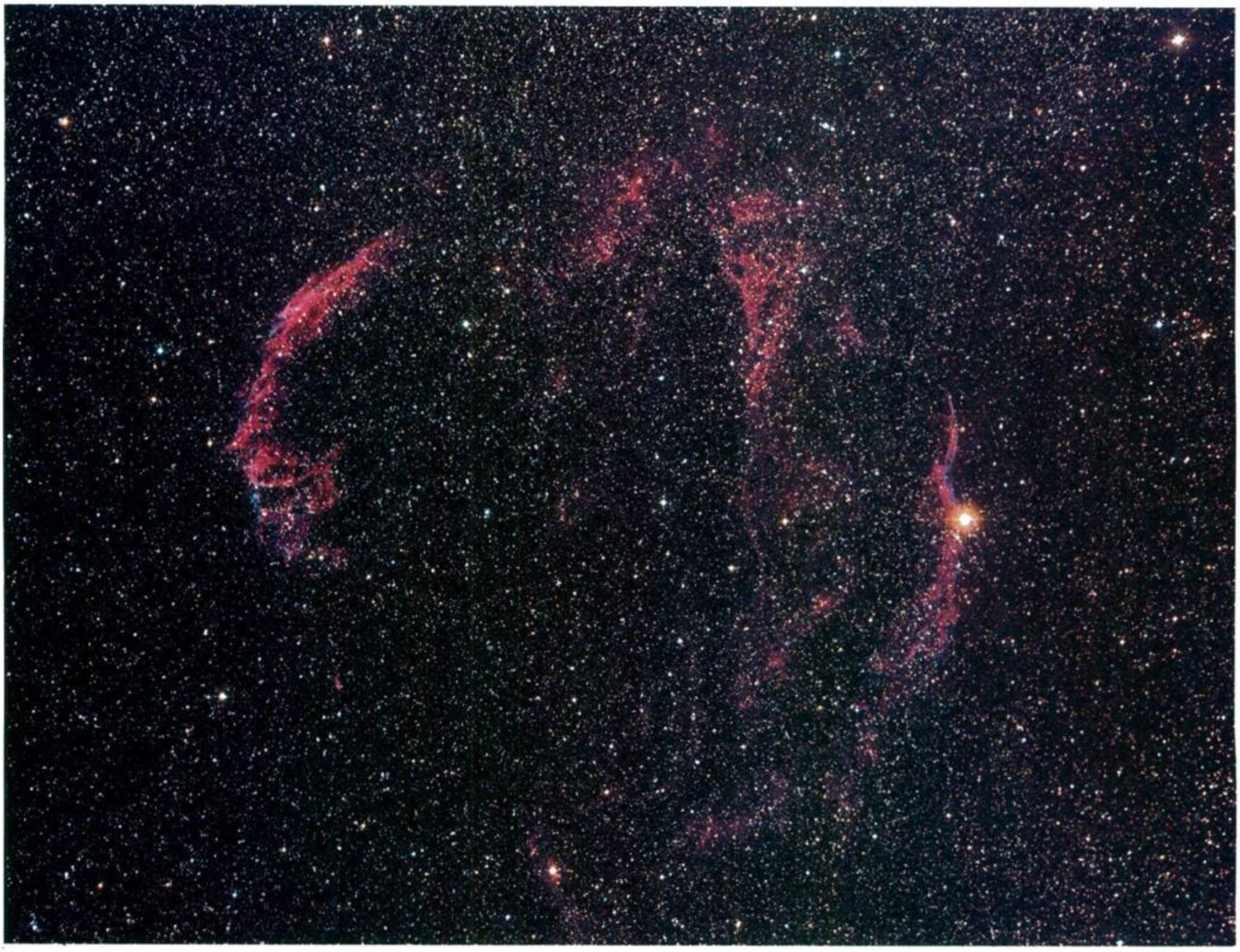
The binary star **16 Cygni** (OΣ 46) is a fine wide pair of yellow 5th-magnitude stars about 70 light-years away.

The Crescent Nebula
(14-inch f/7 SCT, hypered Fuji SHG400 film, composite of two 50-minute exposures)

Albireo
(24-inch f/8 reflector, Apogee AP-7 CCD camera, 2-second exposures through red, green, and blue filters)



Tim Puckett



Bill and Sally Fletcher

The Veil Nebula
(8-inch Schmidt camera, Tech Pan 2415 film, composite of 16-minute red, 60-minute green, and 65-minute blue exposures)

Separated by 39", this pair of virtual solar twins resembles a distant set of car headlights. Look for it about 5½° north of Delta (δ) Cygni, the westernmost star in the Northern Cross. Astronomers recently discovered that the dimmer of the pair, 16 Cygni B, is accompanied by a planet (but don't expect to see the planet, it was discovered by its gravitational influence on the star). You can see 16 Cygni in the same field as planetary nebula NGC 6826 and the galaxy UGC 11465.

A nice multiple star system for binoculars is **Omicron^2 [o^2] Cygni.** It is a combination of 3.8-, 4.8-, and 7.0-magnitude stars, separated by a generous 337.8" and 106.8", respectively. The brightest member is yellow, while the two fainter companions are blue. In large telescopes, look for fainter stars in the area around the trio.

A famous binary star, **61 Cygni**, has an orbital period of about 650 years. The 5.2- and 6.0-magnitude stars appear golden, though I noted the fainter member of the pair to be somewhat more orange. In 1838, German astronomer Friedrich Wilhelm Bessel calculated the system's distance from the sun using triangulation methods. His distance of 10.3 light-years is very close to the modern value of 11.4 light-years. Bessel's observations of 61 Cygni proved that even the closest stars are extremely far away.

61 Cygni
(12.5-inch f/8 reflector, Tech Pan 2415 film, 10-minute exposure) Alfred Lilge

Open Clusters

Cygnus is a treasure trove of open clusters — assemblages of stars often found inside an emission nebulae. Where the North America Nebula lies today, an open cluster will exist in the future. The whole range of clusters may be seen in Cygnus, from the bright M39 to those that are challenges in all but the largest amateur telescopes.

We'll start in the northeastern part of Cygnus. **M39** (NGC 7092) is easily visible in binoculars 8° east-northeast of Deneb. It is a much better target for binoculars or small telescopes than for medium or large instruments. M39 contains about 30 stars in an area about ½° in diameter. At an estimated *distance of 800 light-years*, this is the nearest cluster in Cygnus. The cluster itself is about 7 light-years across.

About 3° due north of M39 lies **NGC 7086**. This cluster is large, about 15' across. The brightest of this scattered group of stars fall in the 9th- to 11th-magnitude range. An estimated 50 stars belong to this cluster. How many can you see?

About 1° south of M39 and 1/2° north of 71 Cygni lies **NGC 7082**. It is large, slightly richer than the surrounding field, elongated in an east-west direction, and contains a mixture of brighter and fainter stars.

Swing west toward Deneb. **NGC 6996** (also listed as 6997) is located 2½° southeast of Deneb in the North America Nebula, approximately where Ohio would be. In a 10-inch f/6 telescope, it looks sparse, roundish, about 7' across, with about 15 stars that are not concentrated but are slightly richer than the field. Immediately to the west of the cluster is the 20'-long dark nebula B353.

Now go 8° southwest of NGC 6996 to find **M29** (NGC 6913). This compact group of about a dozen 8th- to 9th-magnitude stars forms a trapezoid sprinkled with fainter members. Easily found 2° south of Gamma (γ) Cygni, it forms a clump in a dusty region near the edge of the Great Rift. If located in a dust-free part of the sky, M29 would be about three magnitudes brighter. This is one of the least impressive open clusters in the Messier catalog.

Lying 6° northwest of M29 is **NGC 6866** — the richest cluster in Cygnus. It may be found at the intersection southeast of Delta and southwest of Omicron^1 Cygni. It consists of about 80 stars, more than half between 10th and 14th magnitude. Comparable in size to NGC 6819 — it's about 6' in diameter.

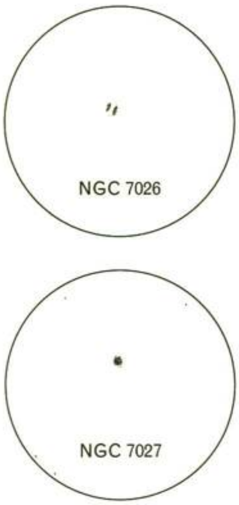
Keep going northwest another 5° to **NGC 6811**, the easternmost open cluster. You can also pick it up by sweeping 2½° northwest of Delta Cygni. The cluster consists of about 70 stars 10th-magnitude and fainter. In a 10-inch f/6 Schmidt-Cassegrain at low power, this cluster can be described as relatively large, relatively faint, and without a central concentration of stars.

We'll end our tour of Cygnus open clusters with **NGC 6819**, 6° almost due south of NGC 6811. It lies due west of Gamma Cygni and due south of Delta Cygni, forming a right triangle. This faint cluster, when viewed with the same equipment as 6811, has a butterfly-shaped group of faint stars with a double star on the lower right.

M39

(16-inch f/5 reflector, 10-minute exposure)

Jack Newton



Eyepiece Impressions of NGC 7026 and NGC 7027

(11-inch f/10 reflector for NGC 7026, 10-inch f/5.6 reflector for NGC 7027) Alan Goldstein

Planetary Nebulae

Cygnus is graced with many bright and interesting planetary nebulae, which form when solar-type stars puff off their outer layers at the end of their lives. Several rate at the top of my "personal favorites" list.

NGC 6826 is an 8.8-magnitude, 26"-diameter object called the Blinking Planetary. Locate this object about 6° north of Delta Cygni or ½° east of 16 Cygni. The blinking has nothing to do with the physical nature of the nebula, it has to do with the physical nature of the observer. While observing this compact green "fuzz-ball," use averted vision so the photons impact different areas of the rods in your eye. Occasionally, the photons will hit your optic nerve — where no light receptors are located. When they do, the object appears to blink, or wink out briefly.

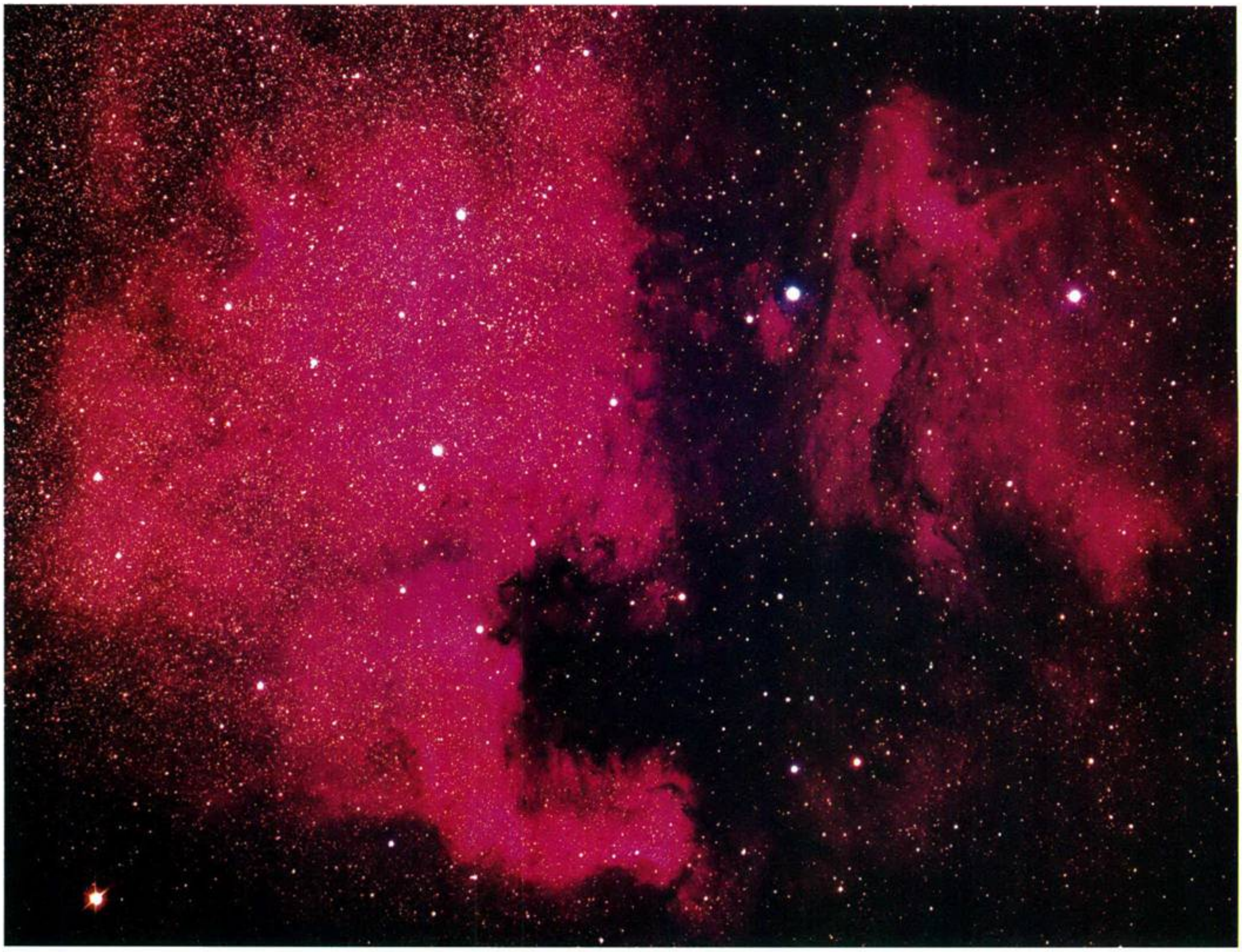
In the late 1970s, while using a 21-inch f/5 scope, I noted that when the nebula blinked, the central star seemed to absorb the color and become bright green. When the nebula reappeared, the star lost the color and became whitish again. I have not spoken with anyone else who has noted that particular phenomenon, although the effect was sufficiently startling for me to retain a vivid image even 20 years later. The blinking effect is not seen by everyone, although it should be seen by anyone using averted vision. Scan around the field — the glow of the planetary nebula should disappear when it hits your optic nerve. Try it and report your findings to *Astronomy*.

Located near the Cepheus border, **NGC 7008** is the largest bright planetary in Cygnus — a hefty 86" by 69" in size. It glows at magnitude 10.7 and appears as an oval disk. Look carefully, because the surface brightness is spread out, and you may pass over it if you scan too quickly through the field. Larger instruments should reveal a dark central hole, with an embedded 13th-

M29

(14.5-inch f/5 reflector, hypered Tech Pan 2415 film, 60-minute exposure)

Martin C. Germano



George Greaney

magnitude central star. Several field stars may be observed on or near the nebulosity, depending on the aperture.

NGC 7026 is a highly elongated (29" by 13") planetary nebula of magnitude 10.9 immediately north of 63 Cygni in the rich star fields north of Deneb. The 15th-magnitude central star requires large scopes to detect, but instruments in the 10- to 12-inch range show brighter patches on either side of its short axis. A bright field star is located nearby. I have not seen any color, even in a 30-inch telescope.

NGC 7027 is another favorite. This box-shaped 18" by 11"-diameter planetary is located slightly less than 2° south of Xi (ξ) Cygni. Its main claim to fame is the color, a vivid green in large telescopes. Conspicuous at magnitude 8.5, NGC 7027 is still bright green but less intense in smaller instruments. It bears magnification well, and while the overall shape is more distinct, it does not show much internal structure. This object appears to be rather oval in smaller optics. The central star is deeply embedded in dense nebulosity that was ejected by the star near the end of its life, when it was a red giant.

NGC 7048 is another large planetary nebula. The large oval disk is 60" by 50". At magnitude 12.1, this object has a low surface brightness. The 18th-magnitude central star is beyond the reach of all but the very largest amateur telescopes, although it can be imaged fairly easily with a CCD camera. Search for this object 2° northeast of Xi Cygni.

Supernovae and Wolf-Rayet Nebulae

NGC 6888 (the Crescent Nebula) is associated with the magnitude 7.5 Wolf-Rayet-type star HD 192163. You can find it in a rich star cloud about 2½° southwest of Gamma Cygni. The oval wisp is visible in binoculars in the Davis Mountains of southwest Texas, but it is almost impossible to see with a 6-inch telescope from less ideal sites. This nebula was formed by gas violently streaming away from a massive, highly energetic Wolf-Rayet star. If the solar wind is a gentle breeze, a Wolf-Rayet star's wind is a raging hurricane. Wolf-Rayet stars are very rare because only a few stars ever become Wolf-Rayet stars, and they only spend a small portion of their lives in this state. They are destined to go supernova.

The North America Nebula
(6-inch f/7 refractor, hypered 120 format Fuji SHG400 film, two 60-minute exposures)

The **Veil Nebula** (NGC 6960, NGC 6992–95) is one of the most fascinating objects in the sky. It was formed 10,000 to 15,000 years ago when a massive star's life ended in a brilliant supernova explosion. Today, its remnant forms a wispy, irregular string of cirrus-like gas clouds in an asymmetrical shell about 2° in diameter. Sometimes called the Cirrus Nebula or the Cygnus Loop, the eastern and western arc-like clouds may be seen in binoculars under very dark skies. Almost any telescope will reveal some degree of detail.

For those first attempting this object, target the 4th-magnitude star 52

Cygni. The nebulosity of NGC 6960 streaks above and below this star. Move the telescope 2° northeast and the brighter curved arc of NGC 6992–5 will become apparent. This nebulosity is actually brighter. The delicate wisps take on an almost surrealistic appearance in telescopes 16 inches and larger. The detail strongly resembles intertwined cirrus clouds that makes them nearly impossible to draw. NGC 6979 can be seen, along with numerous smaller shreds that do not have an NGC designation. This supernova remnant is a recommended target for any deep-sky observer attending a star party where a large telescope is set up. It presents a visual image you will not soon forget.

Emission and Dark Nebulae

The Cygnus star cloud is well-endowed with emission nebulae, which are giant stellar nurseries. The **North America Nebula** (NGC 7000), located 2° east of Deneb, is the brightest. The nebula may be seen under very dark skies with the unaided eye, although binoculars provide the best view of the nebula as a whole. A 4- to 6-inch rich field telescope with a field in excess of 2° will also offer a memorable glimpse of this continent-shaped mass of glowing hydrogen. Although the North America Nebula appears reddish in color photos, it appears colorless to the eye. Embedded hot stars strip electrons from atoms in the nebula. When the electrons recombine with other atoms, the atoms emit red light, giving the nebula its famous reddish hue. The nebula is defined by dust clouds that create the "Atlantic" and "Gulf" coasts (this dark area is LDN 935). The "Pacific" coast, particularly along Mexico, also sharply contrasts the nebula and surrounding star field.

The **Pelican Nebula** is a challenging emission nebula that is part of the North America complex. Designated IC 5067/70, this is not an easy object to observe. I have glimpsed it with small aperture instruments (6 inches) under the dark skies in the Flint Hills of Kansas and the Davis Mountains. Dry, transparent skies are essential. A nebula filter on a rich field telescope may also prove valuable in detecting this elusive nebular complex. Using the North America Nebula as a map, the Pelican Nebula is positioned like a giant hurricane off the east coast, stretching from the "Caribbean" to "New York." Most of the detail in the Pelican is visible only in photos and electronic imagery.

NGC 7008

(14.5-inch f/5 reflector, hypered Tech Pan 2415 film, 60-minute exposure) Martin C. Germano

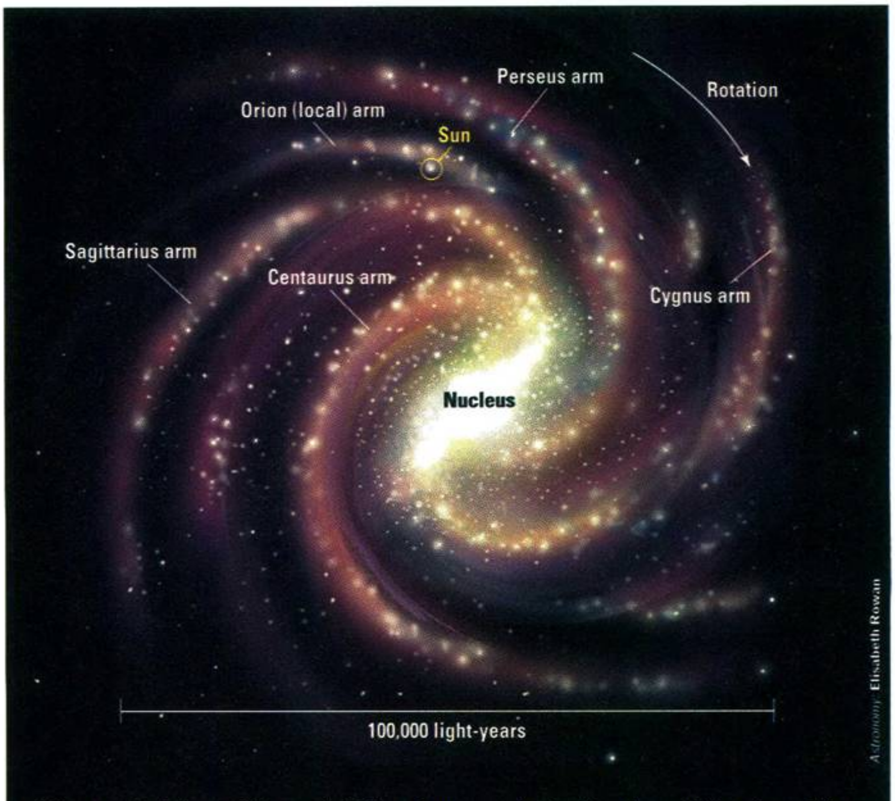
About 5° northeast of Deneb near the Cygnus-Cepheus border is **Le Gentil's Nebula**, also known as Lynd's Dark Nebula 1027, a large dark nebula covering 10 square degrees. Its shape is somewhat wider on the east side and resembles a dark dagger. Easily seen with the naked eye when the Milky Way is readily visible, it can be seen with binoculars, but is too large for most rich field scopes. This object is not plotted on most star atlases.

Farewell to the Swan

Few galaxies can be seen in Cygnus because the thick dust and star clouds block the light of more distant objects. The brightest galaxy is 12.8-magnitude UGC 11465, which can be found in the same field as 16 Cygni. It measures 1' across and is one of the most overlooked objects in Cygnus.

Despite the lack of galaxies, Cygnus contains a stunning collection of beautiful objects. On the next clear, comfortable late summer night, see what the Swan has to offer.

Alan Goldstein (Deepskyspy@aol.com) is a naturalist and avid deep sky observer from Louisville, Kentucky. In 1976 he founded the National Deep Sky Observers Society.



Astronomy: Elisabeth Rowan

When you look toward the constellation Cygnus, you're looking through the plane of the Milky Way Galaxy toward the Cygnus spiral arm. Dust within the galactic plane prevents us from seeing stars and deep sky objects in the Cygnus arm, however. Most of the stars and deep sky objects in the constellation Cygnus are located within our own local spiral arm, and the long axis of this arm forms the Cygnus Star Cloud. Because the constellation Cygnus lies within the dust-laden galactic plane, very few galaxies can be seen in this direction. Astronomers discovered the Cygnus arm with radio observations.

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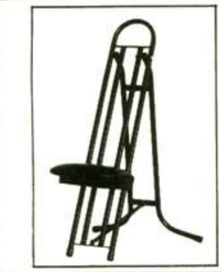

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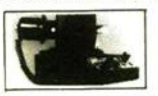

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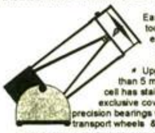

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Not too

A few simple tips for picking binoculars.

by Stephen J. Edberg

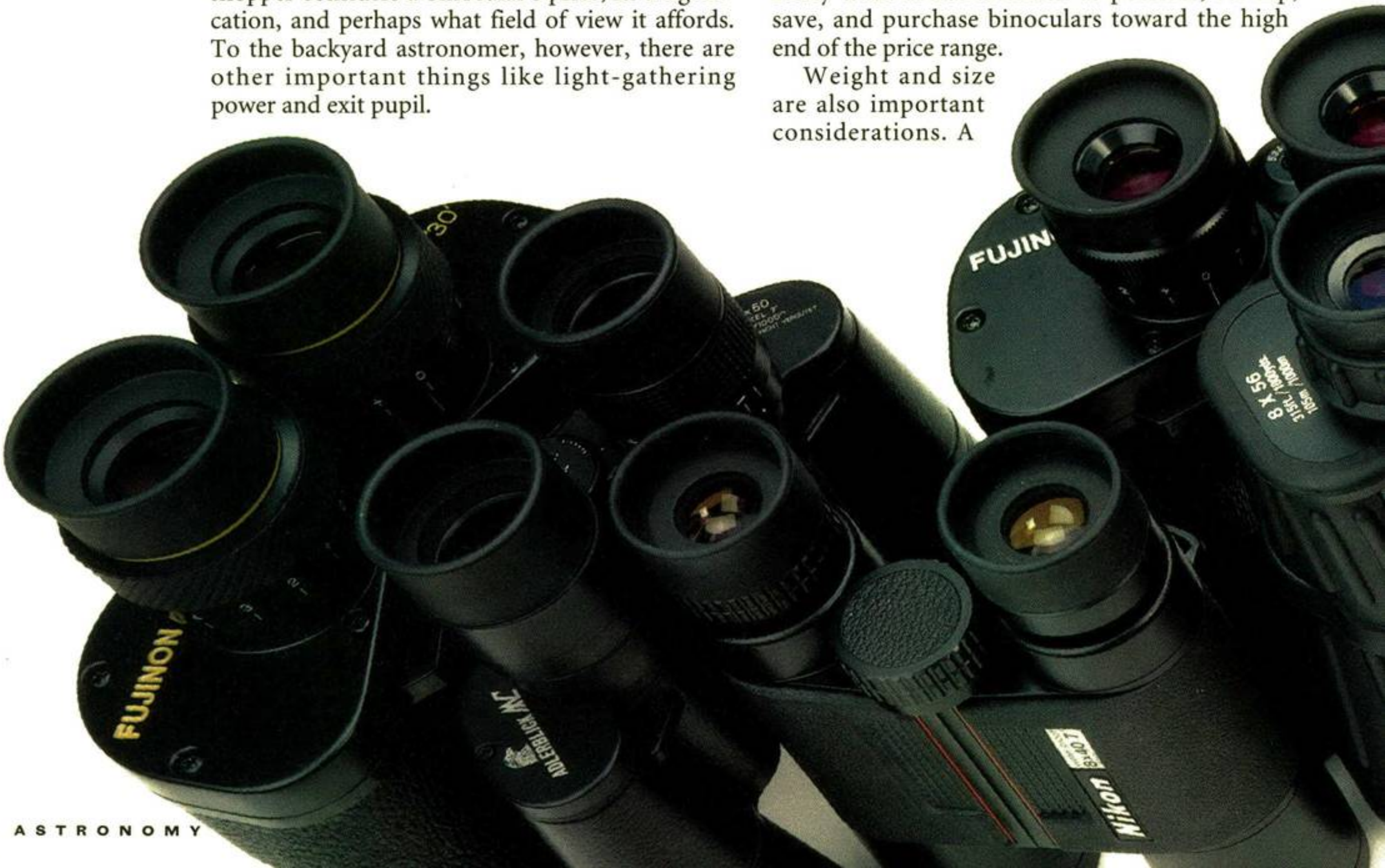
SO YOU'RE LOOKING TO PURCHASE A PAIR of binoculars for checking out the stars. A quick glance through ads in *Astronomy*, or even a trip to a local retailer, reveals that binoculars come in a variety of sizes and shapes. And then there's a deluge of facts and stats — 10x42 . . . porro prism . . . center focus . . . multicoated . . . what do all these terms mean? Absorbing all this is almost like trying to sip water from a fire hose.

First, some sage advice: slow down. Decide how you plan to use your binoculars. The average shopper considers a binocular's price, its magnification, and perhaps what field of view it affords. To the backyard astronomer, however, there are other important things like light-gathering power and exit pupil.

Start with the Fundamentals

To choose your ideal binoculars, first consider optical quality. In general, you get what you pay for. While image quality near the center of the field of view may be sharp in most binoculars, edge sharpness generally improves as price increases. Residual color and image distortion is also less pronounced in pricier pairs. Subtle flaws in the quality of an image will become more noticeable as you push binoculars to their limit and stretch their ability to discern detail. If you really want to see as much as possible, scrimp, save, and purchase binoculars toward the high end of the price range.

Weight and size are also important considerations. A



Close

birdwatcher roaming the forest all day may place greater importance on small, lightweight binoculars that won't slow him down. An astronomer planning all-night observing sessions won't care as much about weight and bulk as long as the binoculars can be mounted on a tripod.

Optical design also factors into this balancing act. First of all, for function, stay away from fixed-focus binoculars. They are prefocused for terrestrial viewing; distant stars may look fuzzy. Other binoculars feature eyepieces that focus separately or incorporate a center focus knob to let you focus both eyes at once. Either of these adjustable-focus designs will work well for astronomy.

"Straight-through" binoculars use a roof prism to fold the optical path back on itself for the sake of compactness. By using a single roof prism instead of an offset pair of right angle prisms (called porro prisms), this design reduces a binocular's weight and bulk. However, roof prisms might create irritating spikes around bright stars, planets, and the moon, caused by light scattered off one edge of the roof prism. The effect is minimized in more expensive units. But regardless of price, the roof prism design doesn't offer as many magnification and lens-size options as the porro-prism binoculars. Roof-type prism binoculars are also harder to mount on a tripod. Porros are often easier to hand hold than roof prism binoculars simply because of their shape.

7x50 7°30'
FUJINON

But porro-prism-type binoculars are not fault-free. Less expensive ones use prisms made of BK7 glass, which often absorbs a noticeable amount of light, particularly at a visual field's outer edge. More expensive binoculars use BaK4 prisms that do not suffer from this limitation.

Starlight, Star Bright

Regardless of prism and glass type, all binoculars collect light to magnify a distant object and increase its visibility. The amount of light they collect is determined by the size of the two front lenses, called the objective lenses. Magnification is an interplay between a binocular's eyepieces and its objective lenses.

Magnification and objective lens size are indicated by a number, such as 7x50, printed on the binoculars' housing. In this case, 7x50 means a 7 power magnification and a 50 millimeter-diameter objective lens. Seven power (or 10x, 11x, 16x, or 20x) tells you how much closer the scene looks than if no magnification were used. The moon appears eleven times closer in 11x80 binoculars, its diameter swelling to eleven times what the unaided eye sees.

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Of course the amount of light getting through an instrument is also important to observers of the stars. This can be assessed for all binoculars by calculating what's called exit pupil size. The exit pupil itself is a small circle of light that shows up in the eyepieces through a pair of binoculars held at arm's length. The larger the exit pupil, the more light that comes out of the eyepiece into your eyes. You can calculate how wide this circle is by noting the binocular's specification number. Exit pupil equals the objective lens diameter (in the case of 7x50s, 50) divided by the magnification (7x). For 7x50s, the exit pupil is 50 divided by 7, or 7.1mm. It's the exit pupil measurement that best describes which binoculars are best-suited for astronomical purposes.

The exit pupil size also gives you an idea of how well your dark-adapted eye will work with a particular pair of binoculars. An eye's pupil opens up to 7mm when the observer is young and fully dark-adapted. But maximum dilation shrinks with age. By the time you're 65, pupils may not dilate beyond 5 mm. Because the eye cannot use light from an exit pupil bigger than the eye's pupil, a pair of binoculars with an exit pupil larger than a dilated pupil magnifies but does not brighten the view. As a general rule, always select binoculars that feature exit pupils between 5 and 7mm. That said, if you are middle-aged, choose binoculars that offer exit pupils between 5 and 6mm. Younger observers, in their teens, 20s, or 30s, can stick with binoculars that yield close to 7 mm.

Exit pupil size only tells part of the story when it comes to considering how much light reaches your eyes. It's a given that glass absorbs some of the light passing through it. On top of that, every time light moves from air to glass or glass to air, as happens a lot with binoculars, some of the light is lost. Manufacturers minimize this effect by applying special coatings on the glass surfaces. Besides increasing light transmission, coatings boost contrast and reduce the chances of seeing irritating ghost reflections of bright objects, especially at night.

Nowadays, all binoculars have anti-reflection coatings on at least some glass surfaces. You can see this for yourself by looking at reflections in a binocular's front lenses. Less expensive, "coated" binoculars have a blue-colored coating on the outermost lens surface. If coatings are on one or more lenses, you see both white (from uncoated lenses) and blue (from coated lenses) reflections. "Fully coated" means that all the lenses have an anti-reflection coating on their surfaces; they show only bluish reflections. "Fully multi-coated" optics show weak greenish or reddish reflections. They offer the greatest transmission of light, but are also more expensive.

But I Thought . . .

. . . a big front lens meant wider views. A larger set of objective lenses lets you see fainter things and enjoy brighter images. Field of view depends entirely upon what eyepieces the binoculars use.

. . . rubber-armored binoculars were waterproof. While most waterproof binoculars are armor coated, not all armor-coated binoculars are waterproof. Armor coating adds durability, not waterproofness. Also, armoring does not necessarily mean shockproofing.

. . . optical coatings protected the lenses. Coatings enhance contrast and light transmission. They do not protect glass from scuffs and scratches.

Eyepieces are also important to a good set of binoculars. Their optical design determines eye relief and field of view. Eye relief is a measure of how far from the eyepiece an observer's eyes must be to see the whole field of view. Short eye relief makes using a pair of binoculars difficult for most eyeglass wearers.

Most manufacturers supply an eye relief measurement in the binocular's technical specifications. You can also measure it by aiming the binoculars at a bright source of light and projecting the exit pupil onto a card. Move the card back and forth until the exit pupil comes into sharp focus. Now take a millimeter rule and measure how far the eyepiece is from the card to get eye relief in millimeters. A more practical way is to simply look through the binoculars with your glasses on. If you can comfortably see a full field of view, eye relief is adequate. Remember that if you don't suffer from astigmatism you can use binoculars without your glasses by simply refocusing them.

Seeing Far and Wide

A final statistic is field of view, a measure of the width (really, the diameter) of a scene in the binoculars. Often quoted as "394 feet at 1000 yards," astronomers are more interested in how this translates into angular field of view. If this number is not given in the binoculars' documentation, figure it out by dividing the width value (in feet) by 52.5 to get the field of view in degrees. Using the example above, 394 feet divided by 52.5 yields a field of view of 7.5°, about 15 diameters of the moon. As you might expect, higher magnifications have reduced fields of view.

You, the Savvy Consumer

Hold the binoculars you're thinking of buying at arm's length with the lens covers off. Look for a circle of light in the eyepieces. Internal prisms that use more desirable BaK4 glass look completely round; ones with BK7 glass produce clipped edges. Now look at the front lenses. Multicoated optics have faint magenta or green reflections, as well as white. Fully multicoated units produce only faint greenish or reddish reflections. To see if a set of binoculars will hold their focus, press down on the covered eyepieces. If the eyepiece bridge moves under very little pressure, focus could shift inadvertently. How do the binoculars handle? Put on some thick gloves. Are they easy to focus? Now look through the binoculars with both eyes. Alternately cover and uncover one of the lenses — if the image shifts or you're forcing two images together, there's a collimation alignment problem. Check for edge sharpness by stepping outdoors to view a distant, detailed object. Does the view become blurry as you move from the center of the field of view to the edge?

FUJINON
7X50

Binoculars courtesy of Casanova's Outdoor Adventure Center. Photos by *Astronomy*: Jim Forbes

Some binoculars are designed to offer a wider field of view than the average for their magnification. These "wide angle" units do show more, but often at the expense of eye relief and image quality near the field of view's edge.

So what kind of binoculars should a backyard astronomer buy? Even low-end binoculars permit views of the night sky, but more expensive binoculars will be more rewarding in the long run. Remember that a good pair of binoculars lasts a lifetime, for both astronomy and daylight activities. Settle on a pair that is comfortable and easy to use. Your first set of binoculars will be a lifetime ticket into the hobby. Enjoy the view! ■

Stephen J. Edberg is executive director of the Riverside Telescope Makers Conference and has been an amateur astronomer for more than 30 years. By day he works at NASA's Jet Propulsion Laboratory on the Cassini mission to Saturn.

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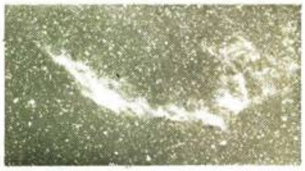

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Rich Zepernick, Cresskill, NJ

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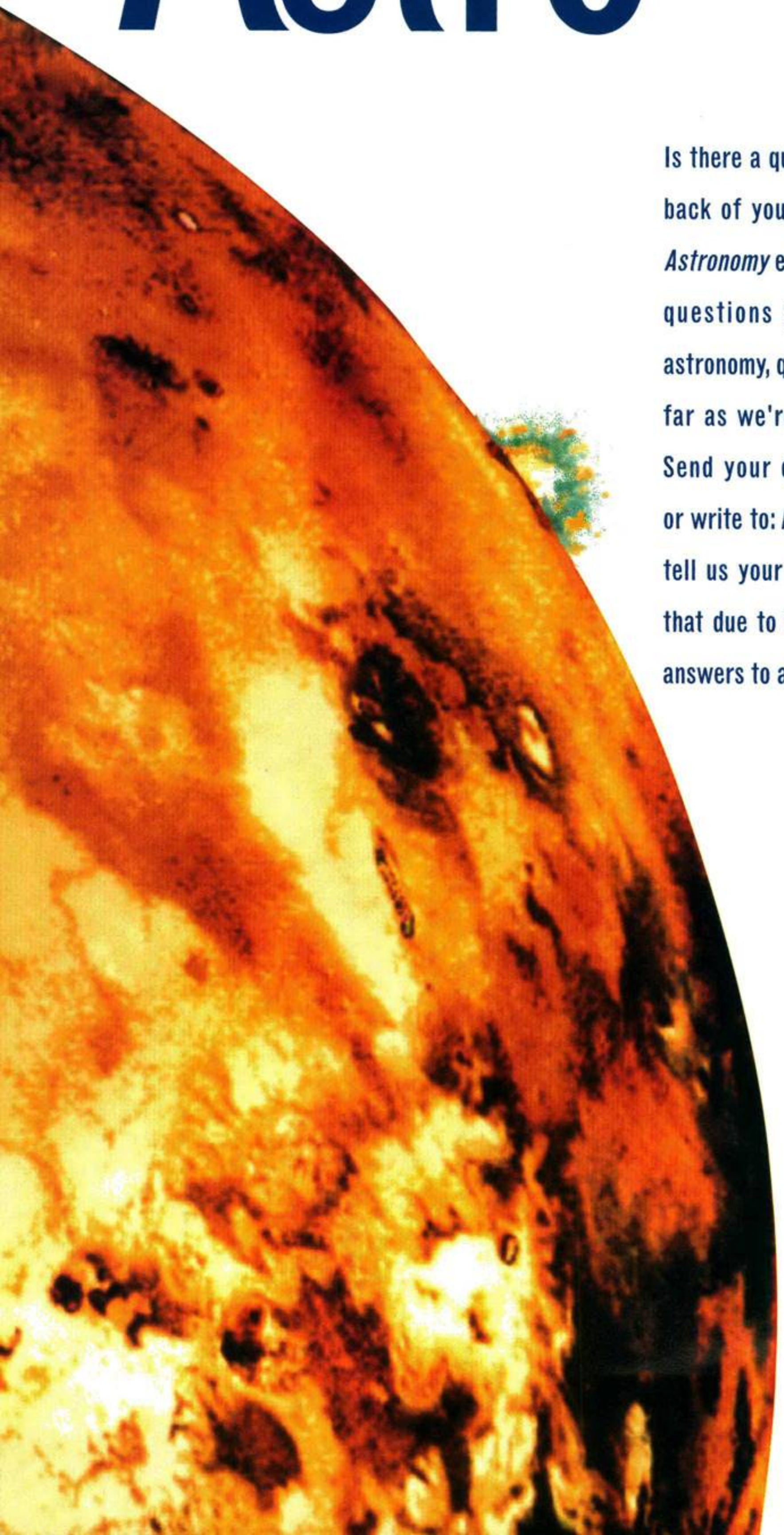
D-19 B&W Developer	1 gal.	$6.95

ask Astro

Is there a question about astronomy that's been gnawing at the back of your mind? We'd like to hear it! Starting this month, *Astronomy* editors will be answering your questions. We welcome questions pertaining to both the science and hobby of astronomy, questions ranging from the simple to the sublime. As far as we're concerned, every question is a good question. Send your query via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53186. Please tell us your full name and where you live. *Astronomy* regrets that due to the large volume of mail, we are unable to publish answers to all questions or respond to each one individually.



A volcanic plume rises high above Io. This moon of Jupiter is the most volcanically active body in the solar system because it is caught in a gravitational tug-of-war between Jupiter and two of the planet's other large moons. NASA/JPL

Q: Is it possible that all galaxies are recycling their own mass? — *Paul Patrick, Mt. Vernon, Ohio*

A: Yes. In fact, galaxies have been likened to giant recycling machines. Astronomers believe that the first galaxies formed about 1 billion years after the Big Bang, when enormous clouds of hydrogen and helium gas collapsed due to gravity. Hydrogen and helium are the two lightest elements and astronomers think they were the only elements cooked up in appreciable quantities during the Big Bang.

What this means is that the first generation of stars only had two sources of fuel available: hydrogen and helium.

Anglo-Australian Telescope Board/David Malin

The massive stars inside this ring are giving off furious stellar winds, forming the nebula.

Fortunately, these are the two easiest elements to fuse into heavier elements, and it's this fusion reaction that powers the sun and other stars.

During their life cycles, stars synthesize a succession of heavier and heavier elements. Stars give this material back to the galaxy by a variety of processes. Every million years, the sun donates a moon's worth of mass back to the Milky Way via the solar wind. This might not seem like a lot, but if you envision 200 billion stars pumping out small amounts of mass each year, it adds up.

The most important contributors to the Milky Way and other galaxies, however, are stars that start their lives with about 10 or more solar masses. These stars explode as supernovae at the end of their lives, returning a treasure trove of material, including lots of heavy elements, to their host galaxies. It's this material, mixed in with gas expelled by all the other stars in a galaxy, that forms the next generation of stars and planets. The iron in your blood, the calcium in your bones, the oxygen you breathe — all of those elements were forged inside stars that died billions of years ago. As Carl Sagan was fond of saying, "We are starstuff." — *Robert Naeye*

Q: If Jupiter's gravity causes so much volcanic activity on its moon Io, why doesn't the sun do the same to Mercury? — *Barbara Weiss, Van Nuys, California*

A: Io is the most volcanically active body in the solar system by far because it has been caught in a gravitational tug-of-war between two of its large sister moons, Europa and Ganymede, and the giant planet. These bodies squeeze and flex poor Io, heating its interior, which in turn results in hyperactive volcanic activity.

The premise of your question is correct: The sun exerts a much stronger gravitational influence on Mercury than Jupiter does on Io. In Mercury's case, however, there are no other planets or moons close enough to cause the "Io effect." The gravitational influence of the other planets is so negligible that Mercury is essentially tugged upon in just one direction: toward the sun. As a result, Mercury's interior is not squeezed and flexed like Io's. — *R.N.*

Q: Why isn't Pluto's orbit in the same plane as the other planets of our solar system? — *Marc J. P. Gouw, Utrecht, The Netherlands*

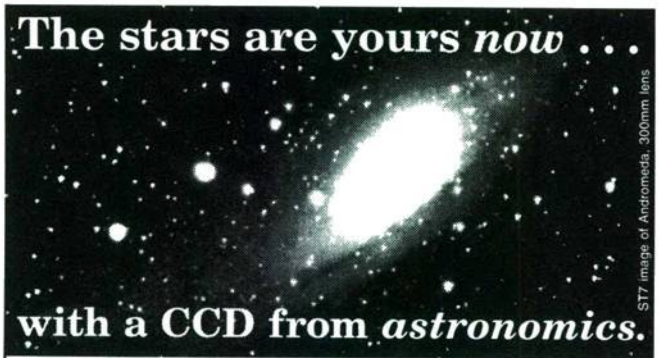
A: All the planets except for Mercury and Pluto orbit the sun within virtually the same plane, known as the ecliptic. Astronomers cite this as evidence that the planets formed inside a flattened disk. Mercury's orbit is inclined by 7° with respect to the ecliptic, presumably due to its close proximity to the sun. But Pluto's orbit is tipped a much higher 17.2°.

While astronomers still don't fully understand the exact process that gave Pluto its high inclination, they think it must be due to complex gravitational interactions with the outer planets, particularly Neptune. For example, Pluto has a special orbital relationship with Neptune called a "resonance." Pluto goes around the sun exactly twice every time Neptune goes around three times. Astronomers think a combination of resonance effects with the outer planets, acting over billions of years, boosted the inclination of Pluto's orbit. In addition, these effects almost certainly gave Pluto its elliptical orbit, which is far more eccentric than that of any other planet in the solar system. — *R.N.*

Q: On February 16, 1997, at 4:30 a.m. (EST), I saw a bright star flare up to between magnitude –1 and –2 for close to two minutes about 10 degrees south of Vega. Then, the star faded. What did I see? — *Christian Miller, Lansdale, Pennsylvania*

A: You most likely saw a satellite reflecting sunlight from a long, elliptical orbit. The Russians have many communication satellites, called *Molniyas*, designed to reach 22,000-mile-high points in their orbits to remain relatively motionless for several minutes. The first *Molniya* was launched in 1965, the most recent one, last December. Judging from your description, the satellite was probably positioned directly over Eurasia at the time you glimpsed it. — *John Shibley*

This Mariner 10 mosaic shows the pockmarked surface of Mercury. Unlike Io, Mercury has no volcanic features. NASA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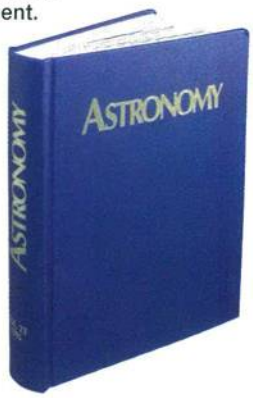

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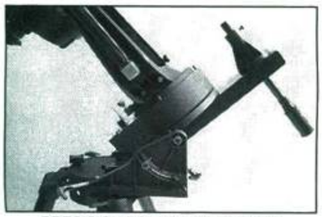
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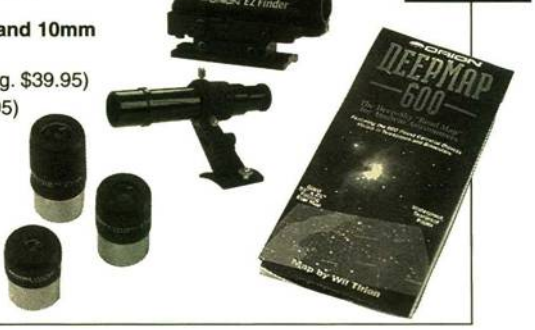
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PRODUCTS

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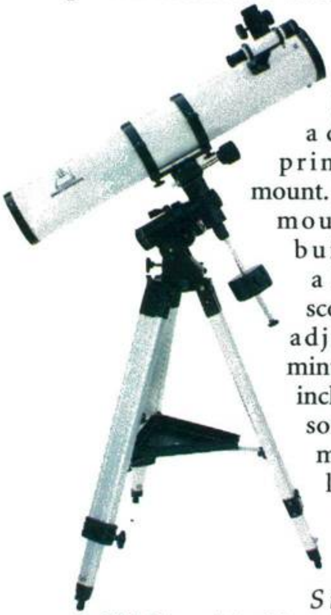
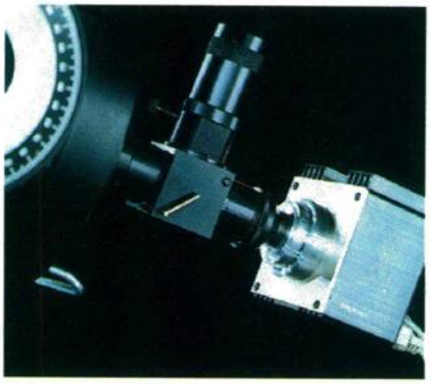


Starsplitter Telescopes, 3228 Rikkard Drive, Thousand Oaks, CA 91362; phone, (805) 492-0489; e-mail, starsltr @aol.com; website, http://www.ez2.net/starsplitter. *The Starsplitter GEM*: $499, plus shipping and handling. Dealer inquires welcome.



Digital, Cooled CCD Camera

The Pegasus is a 658 by 496 pixel (4 by 6mm), 12-bit, cooled CCD camera offered by Astrostock. The imaging chip is cooled to –30° C to reduce electronic noise during long exposures. Communication between the camera and its host computer is all-digital through a single cable, which uses a rear-mounted DB25 connector. The camera's housing mounts to the telescope or an eyepiece adapter through a T-adapter. With an optional upgrade, the Pegasus transfers imagery at a data rate of up to one frame per second. User software works with Windows to allow image-taking as well as picture storage and display. Camera functions are written in the C computer language, enabling users to custom-write their own commands. The Pegasus is 4½ inches wide, 4½ inches high, 2¾ inches deep, and weighs 2¼ pounds.

Astrostock, 2195 Raleigh Ave., Costa Mesa, CA 92727; phone, (714) 722-7900; fax, (714) 646-7578; e-mail, jonsanf@ interserv.com. *Pegasus CCD Camera*: $1,795; *Pegasus Color CCD Camera*: $1,925. Frame memory upgrade: $49.95; 1.25-inch telescope adapter: $45. Shipping and handling extra.

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USER'S MANUAL

Mæstronix Inc., 2025 Lavoisier Street, Local 195, Ste-Foy, Quebec, Canada G1N 4L6; voice, (418) 681-6567; fax, (418) 681-6250; e-mail, beaucha@maestronix.com; website, http://www.maestronix.com. *The Eurêka 2001 Kit*: $750, plus $33 shipping and handling.

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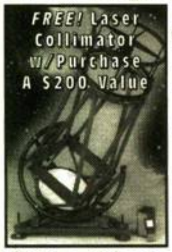

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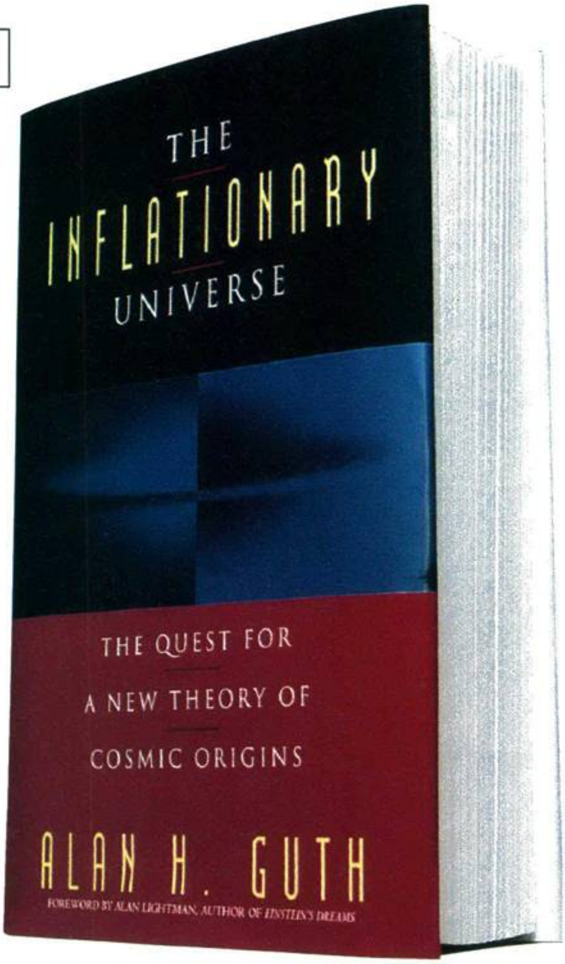

The Inflationary Universe: The Quest for a New Theory of Cosmic Origins

Alan Guth, 384 pages, Addison Wesley Longman, New York, 1997; ISBN 0-201-14942-7, hardcover, $25.

▶ The quest to explain all of nature's processes in one theory may be the one thing that binds together cosmology and particle physics. For at least 50 years this quest has not only baffled leading theorists, it has also been the mark against which all proposed theories must be measured. What's the pot of gold at the end of the rainbow? The Grand Unified Theory, or GUT for short — the great unsolved mystery of creation.

One of the interesting developments in modern cosmology is how it links the realm of the very small, such as the GUT, and the realm of the very large, the universe. The traditional big bang theory has become widely accepted because it appears to give an accurate picture of how the universe evolved. Unfortunately, the universe does not completely agree with the big bang theory as it was initially conceived. For example, the observed homogeneity of the universe and the precise balance of its energies are almost too perfect, as if something had come along and smoothed out all the glitches we would otherwise expect to find.

Particle physics has unified three of the four fundamental forces of nature — electromagnetism and the strong and weak nuclear forces — into a single, underlying force manifested just after the moment of creation. Scientists have also discovered deeper levels of nuclear structure. A modification of the big bang theory that incorporated this research was needed if the scientific community was to step closer to the Grand Unified Theory.

Such a modification was introduced in 1979 by MIT physicist Alan Guth. This model, called the inflationary universe, postulates that the universe experienced a fleeting period of faster-than-light expansion moments after its birth, inflating in size from a region a trillion times smaller than a proton to a marble-sized universe in an infinitesimally small fraction of a second. The history behind the idea, its modifications of the Big Bang, and the basis for its general acceptance are the subjects of this book.

The book is fascinating because it is presented as a rough chronological account of Guth's road to discovery, starting with his graduate student days. It gives the reader an insight into academic research and discovery; timely intervention of fate and good luck play roles equal to that of hard work and gifted genius in determining the final outcome. Guth's preoccupation with the elusive monopole (a particle having one isolated magnetic pole) is a common element that surfaces throughout the book. As the rabbit hole led Alice to Wonderland, the monopole leads Guth to the Grand Unified Theory and eventually to the formulation of the inflation theory.

The Inflationary Universe is well written by an authority in the field of cosmology. In lieu of complex formulae, Guth offers explanations of the logic supporting the theories of cosmic origin. His is a unique perspective, and the book not only provides the reader with a viewpoint of the universe as it is seen today but also introduces, in a very human context, the scientists and researchers who have developed the various theories. While not exactly light reading, the book makes for an excellent addition to anyone's astronomical library.

— **Lee Vande Visse**

Other Books

Yerkes Observatory, 1892-1950

Donald E. Osterbrock, 384 pages, The University of Chicago Press, Chicago, 1997; ISBN 0-226-63945-2, hardcover, $40.

▶ Yerkes Observatory, built more than a century ago by the University of Chicago and financed by robber baron Charles T. Yerkes, housed "the largest and best . . . telescope in the world" and was one of America's first big-science centers. Osterbrock, drawing on his experiences as historian of astronomy, practicing astrophysicist, and director of Lick Observatory, offers a comprehensive history of the birth, near death, and resurrection of this research institution. He carefully examines the observatory's evolution under changing directors, its star pupils, including Edwin Hubble, and its ongoing struggles to obtain necessary funding. Fascinating, readable, and peppered with numerous archival photos, this volume serves as an important addition to the history of astronomy.

Astronomy Smart Junior

Michael L. Bentley, 188 pages, Random House, New York, 1997; ISBN 0-679-76906-4, softcover, $12.

▶ Targeting children in grades six through eight, this addition to the Princeton Review "Smart Juniors" series explores the science of the solar system and beyond. Fun and kooky characters Bridget, Babette, and Barnaby, accompanied by their pudgy feline Beauregard, lead a laughter-filled tour of the solar system that includes stops

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Filter Adapter - 96" .... $11 1 1/4"	$15
Finderscope 8x20 for C90-erect image....$54 BKT	$12
Finderscope 5x24 STG ...$29 6x30	$39
Finder Bracket (Quick Release) 8X50	$42
7x50 III POLAR AXIS Finder	$95
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Focuser Assy 1 1/4"	$29
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Lens Pen	$5
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LPR Filter(Nebular #2.....$129, #5.....$79, ,#7	$89
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Motor FS 114/80 (AC)	$79
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MISCELLANEOUS Peterson Guide	$6
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f4 Reducer lens (for 500mm telephoto)	$72
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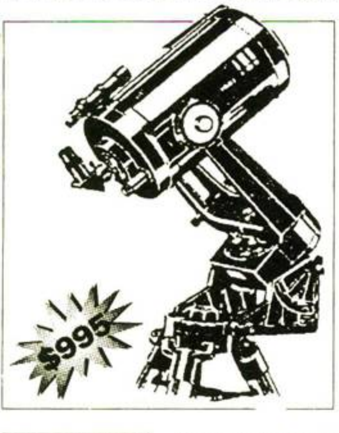

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at colonies on the moon and Mars. The text reads like a storybook, chronicling the "field trip of the century." The narrative is occasionally interrupted by helpful diagrams and illustrations, as well as review quizzes at the close of each chapter. Kids will learn about our galaxy, 20th-century space exploration, the evolution of matter, and how to find constellations. And they'll enjoy every minute.

Imagined Worlds

Freeman Dyson, 216 pages, Harvard University Press, Cambridge, MA, 1997; ISBN 0-674-53908-7, hardcover, $22.

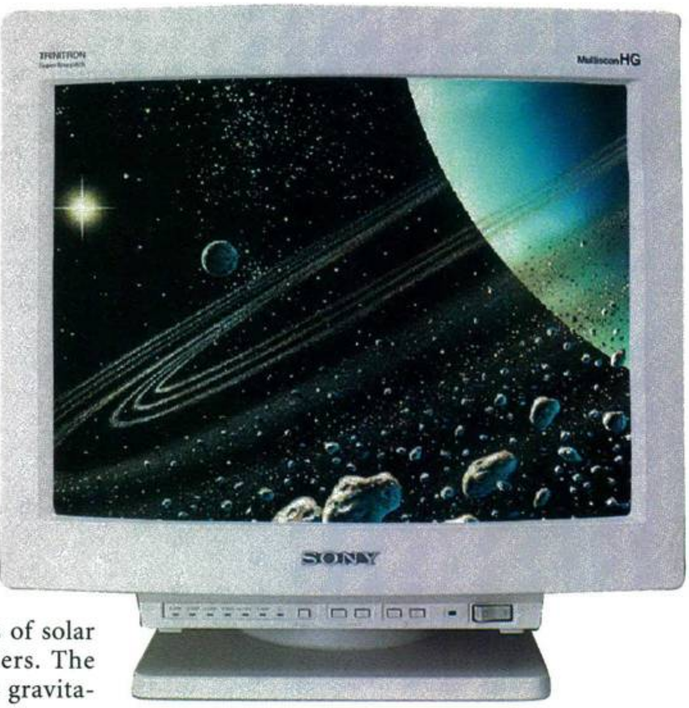
▶ The captivating imagination showcased in his earlier works, which include *Disturbing the Universe*, *Infinite in all Directions*, and *From Eros to Gaia*, surfaces once again in Freeman Dyson's most recent book. Look one million years into the future, he challenges his readers, and recapture our culture's lost long-range vision. Bravely tackling eras normally the domain of science fiction, Dyson speculates about a world that could include human communities scattered around the solar system, the evolution of new species, or even the end of mortality. He draws on science, history, and philosophy in a call for all of us to anticipate and take responsibility for the harm future scientific advances might inflict. He shows us where science and technology may be taking us in hopes of ensuring that it be a place we want to go.

BYTES

Fantastic Space

▶ Bring beauty to your computer desktop with brilliant, high quality space images. *Fantastic Space*, one of 11 space-art screen-saver collections published by Second Nature Software, is a CD-ROM containing 22 breathtaking images from David A. Hardy, the U.K.'s premier astronomical artist. Images can be used as screen savers, as wallpaper, and in image puzzles. Collections of the works of ten other top space artists are also available on CD-ROM.

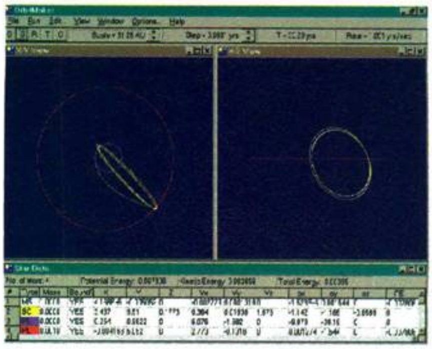
Second Nature Software, 1321 Officers' Row, Vancouver, WA 98661; phone, (360) 737-4169; website, http://www.second-nature.com. Price: $9.98. Minimum PC requirements: Windows 3.1, Windows 95 or Macintosh System 7.1; 4 MB memory; 256 color display recommended.



OrbitMaker

▶ Great for anyone interested in astronomy, *OrbitMaker* is a resource that can be used to determine the characteristics and inherent stabilities of solar systems and star clusters. The program simulates the gravitational interactions of star and planet groups. Nineteen start-up configurations are provided, and others can be constructed and saved. *OrbitMaker* uses three windows: Two provide X-Y and Y-Z coordinate views, and a third, accessed by pressing the left mouse button while the cursor is in either sky display window, shows information about the star closest to the cursor. Information includes star type, mass, spectral class, radius, temperature, luminosity, position, velocity, acceleration, kinetic energy, potential energy, and whether the body is gravitationally bound to other masses. With *OrbitMaker*, gravitational systems will be yours to explore in countless new ways.

Zephyr Services, 1900 Murray Ave., Pittsburgh, PA 15217; phone, (800) 533-6666; fax, (412) 422-9930; e-mail, mail@zephyrs.com. Price: $99.95 + $5 shipping. Minimum PC requirements: Windows 95 or Windows 3.1, mouse, 4 MB memory, and color graphics.



The Webweaver Picks

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EarthRISE
http://earthrise.sdsc.edu/earthrise/main.html

The Nine Planets
http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html

The Solar Data Analysis Center
http://umbra.gsfc.nasa.gov/sdac.html#ECLIPSES

The Solar System
http://www.geocities.com/CapeCanaveral/Lab/2683/index.html

Solar Terrestrial Dispatch
http://solar.uleth.ca/solar/www/images.html

Views of the Solar System
http://bang.lanl.gov/solarsys/

Welcome to the Planets
http://pds.jpl.nasa.gov/planets/

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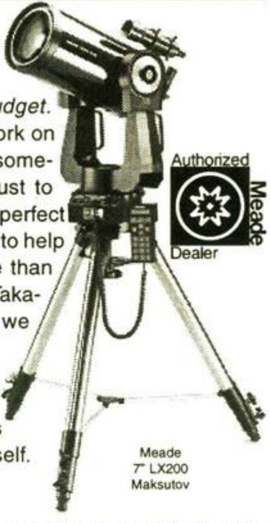

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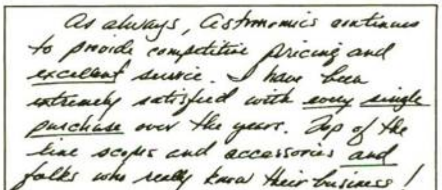

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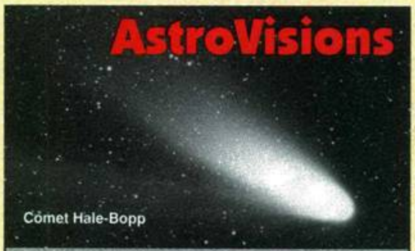

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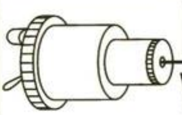

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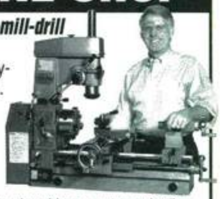

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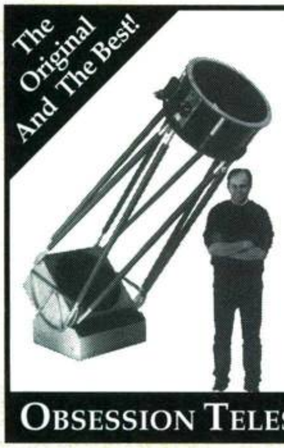

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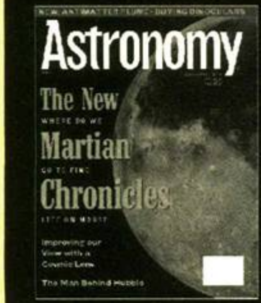

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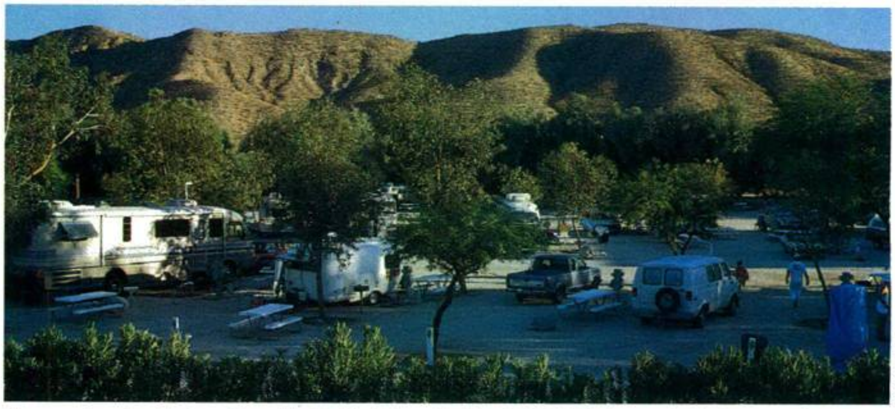
A LOOKING AHEAD

AUGUST

Amateur telescope makers of all ages will gather at the 62nd **Stellafane Convention**, taking place August 1-3 on Breezy Hill in Springfield, Vermont. Activities include amateur telescope making demonstrations, a swap area, and lectures, but the heart and soul of Stellafane is the telescope competition. If you've built a telescope, bring it along, or if you're thinking about building one, come to see how it's done. Watch for *Astronomy*'s associate editor Richard Talcott in the crowd.

Star parties and conventions abound this month — find one near you and share your observing experiences.


Rick Shaffer

The spectacular Mojave Desert is the backdrop for the Nightfall star party in Borrego Springs, California, sponsored each fall by the organizers of the Riverside Telescope Makers Conference.

JULY 30-AUGUST 2

S.M.U.R.F.S. '97 Star Party

▶ Hillman, Michigan. Contact Richard Walker, Robert Longway Planetarium, 1310 East Kearsley, Flint, MI 48507, (810) 760-1181.

JULY 30-AUGUST 3

Mt. Kobau '97 Star Party

▶ Okanagan Valley, British Columbia, Canada. Contact Ann Murphy, P.O. Box 20119 TCM, Kelowna, BC, Canada V1Y 9H2, (250) 764-8478, e-mail rscherer@ awinc.com.

JULY 31-AUGUST 2

Table Mountain Star Party

▶ Ellensberg, Washington. Contact TMSP, P.O. Box 785, Puyallup, WA 98371, e-mail TMSP@triax.com.

JULY 31-AUGUST 3

Southern Idaho Regional Star Party

▶ Bruneau Dunes State Park, Idaho. Sponsored by the Boise Astronomical Society. Contact John McVey, (208) 376-6164.

AUGUST 1-3

Stellafane Convention

▶ Breezy Hill, Springfield, Vermont. Contact the Stellafane Convention, P.O. Box 50, Belmont, MA 02178, http://www.stellafane.com.

AUGUST 1-3

Weekend Under the Stars

▶ Foxpark, Wyoming. Contact Marty Curran, 3539 Luther Place, Cheyenne, WY 82001, (307) 635-5944, e-mail mcurran@ sisna.com.

AUGUST 2-9

Nebraska Star Party

▶ Merritt Reservoir, Valentine, Nebraska. Contact Dave Scherping, 640 South 30th Street, Lincoln, NE 68510, (402) 477-2596, e-mail NSP@4w.com, http://www. 4w.com/nsp/.

AUGUST 7-10

Starfest '97 – Annual Observing Convention

▶ River Place Campground, Mount Forest, Ontario, Canada. Contact Andreas Gada, 26 Chryessa Avenue, Toronto, Ontario, Canada M6N 4T5, (416) 761-1798; or Tony Ward, e-mail tward@ visionol.com, http://www.unicom.org/ ~nyaa/nyaa0.htm.

AUGUST 8-9

Montana Starwatch

▶ Ruby Reservoir near Virginia City, Montana. Sponsored by the Southwest Montana Astronomical Society. Contact Mike Murray, Museum of the Rockies, 600 W. Kagy Blvd., Bozeman, MT 59717, (406) 994-6891.

AUGUST 8-9

Susquehanna Summer Star Spectacular

▶ Chestnut Hill Airport, Duncannon, Pennsylvania. Sponsored by the Astronomical Society of Harrisburg. Contact Doug Grove, (717) 652-7097.

AUGUST 8-10

Northwoods Starfest

▶ Hobbs Observatory, near Fall Creek, Wisconsin. Contact Ray Forsgren, 4856 Inlet Drive, Chippewa Falls, WI 54729, http://www.phys.uwec.edu/cvas/.

AUGUST 8-11

Eta Aquilae Star Party

▶ Rucava, Liepaja district, Latvia. Contact the Latvian Astronomical Society, Blvd. Rainis 19, LV-1586, Latvia, or e-mail astro@acad.latnet.lv, http://www.lanet.lv/members/LU/astro/ ast_erg.html.

AUGUST 12

Free Star Party

▶ Ralph Worley Observatory, Shreveport, Louisiana. Sponsored by the Shreveport-Bossier Astronomical Society. Contact Cran Lucas, (318) 797-1524, e-mail clucas@softdisk.com.

AUGUST 25-31

Queensland Astrofest '97

▶ Lions Camp Duckadang, Linville, South East Queensland, Australia. Contact Patrick Scharf, 061-07-3869-0659, e-mail scharfpb@eis.net.au, http://www.ozemail.com.au/~mhorn2/afest97.html.

AUGUST 28-SEPTEMBER 1

Oregon Star Party

▶ Ochoco National Forest, Oregon. Contact the Oregon Star Party Committee, P.O. Box 91416, Portland, OR 97291, or Chuck Dethloff, (503) 357-6163.

CONTACT

Please submit club announcements four months in advance to Looking Ahead, Astronomy, P.O. Box 1612, Waukesha, WI 53187, or to tconley@astronomy.com.

A RESOURCES

Looking for Life on Mars (page 38)

"Was There Life on Mars?" by Robert Naeye, *Astronomy*, November 1996. Discusses the structures found in the martian meteorite ALH84001 and the debate about whether they are signs of ancient life.

"Did Mars Once Have Martians?" by Christopher P. McKay, *Astronomy*, September 1993. Digital images of the martian surface are available from the U. S. Geological Survey on the Internet. Check out their site at http://www-pdsimage.wr.usgs.gov/PDS/public/mapmaker/mapmkr.htm.

Gravity's Rainbow (page 44)

Gravity's Lens: Views of the New Cosmology, by Nathan Cohen (John Wiley & Sons, 1988). A beginner's guide to relativity and cosmology, with a chapter devoted to gravitational lensing.

"Mapping Dark Matter with Gravitational Lenses," by J. Anthony Tyson, *Physics Today*, June 1992. A semi-technical explanation of how astronomers use gravitational lenses to track down the elusive dark matter.

Sky Show (page 58)

Seeing the Sky, by Fred Schaaf (John Wiley and Sons, 1990). This book presents 100 sky projects you can do with the unaided eye.

Observing the Treasures of Cygnus (page 68)

Burnham's Celestial Handbook, Volume Two, by Robert Burnham, Jr. (Dover Publications, 1978). This old warhorse contains a whole section about binocular and telescopic objects in Cygnus.

Webb Society Deep-Sky Observer's Handbook, Volume 3, Kenneth Glyn Jones, editor (Enslow Publishers, 1980). The perfect guide to open star clusters and globular clusters, which are some of the best targets in Cygnus.

Not Too Close (page 76)

How to Choose Binoculars, by Alan R. Hale (C&A Publishing, 1991). An excellent softcover book that gets into detail about astro-binoculars.

Binocular Astronomy, by Craig Crossen and Wil Tirion (Willmann-Bell, 1992). Offers a season-by-season constellation tour of the night sky.

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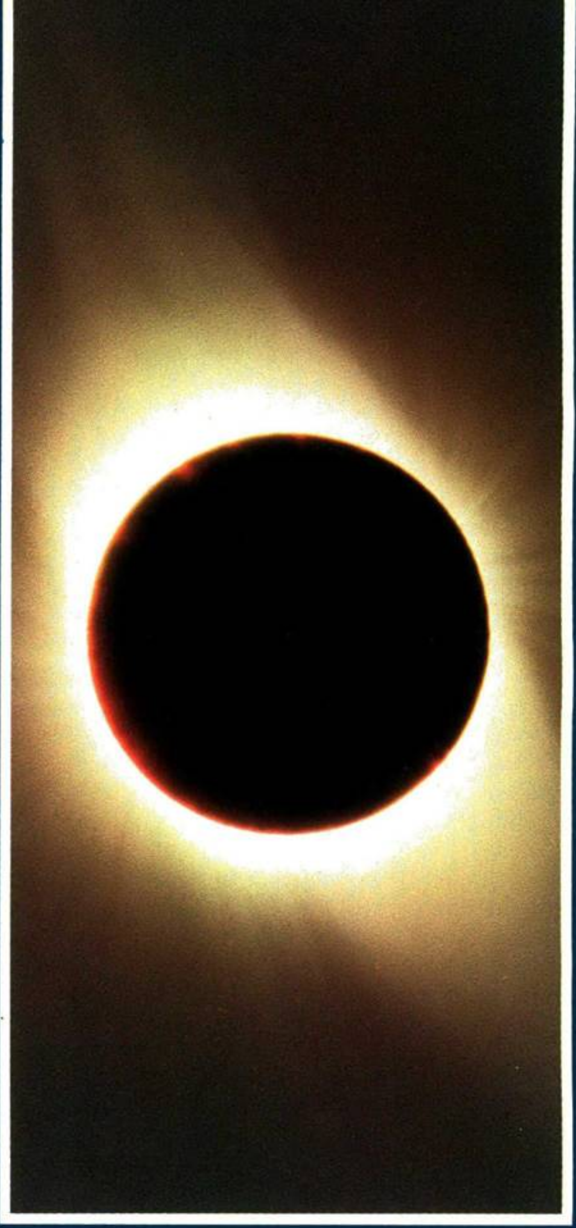

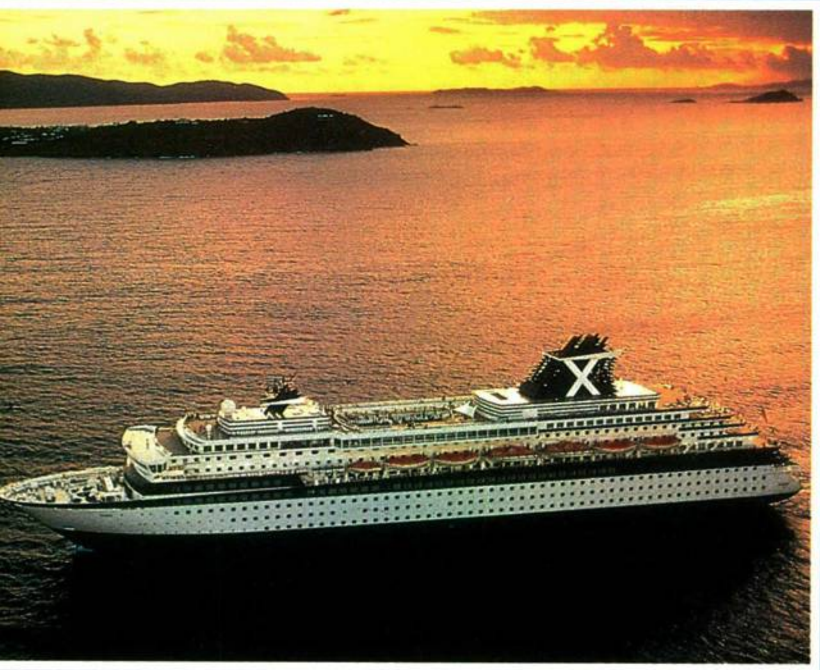

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Dirk Hoppe

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BACKYARD PERSPECTIVE

From Iowa to Eternity

Hale-Bopp may be gone, but it will be never forgotten.

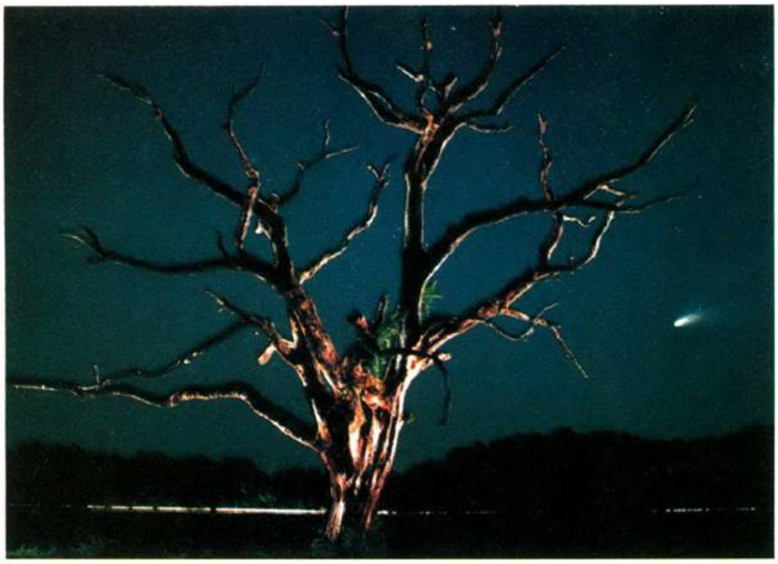
▶ Hale-Bopp, the brightest comet in 20 years, is on its way back into the cryogenic cold from where it came. It pains me that something so utterly beautiful leaves with a tail spotted with the blood of misguided cultists. As its feeble light fades, I send this comet back to the Kuiper belt with better thoughts.

I had been watching the approach of this marvelous interloper from my Davenport, Iowa, backyard since its discovery in 1995. All through the fall of 1996, Hale-Bopp gradually brightened to sport tentacle-like jets of gas and dust. Things really got interesting during the frozen Iowa mornings of early February, when Hale-Bopp started looking like a comet ought to look.

By March 11, the visitor was visible about 15° above the horizon at sunset. That night I mounted an expedition 12 miles north of town, to where there were really dark skies. Seeing was so perfect through my 10-inch Dobsonian that I could glimpse surface features on the setting crescent moon by earthshine. To the south, the Orion Nebula glowed blue and red through the eyepiece like some kind of cosmic chrysanthemum. Then I turned my attention to the main event: Hale-Bopp.

Unlike Hyakutake, which had a pale azure blue to its coma, Hale-Bopp was pearly white. It had a fine curve to

The Rosette Nebula (NGC 2237-9) in Monoceros
CARL WEBER
(6-inch f/7 refractor, hypered Kodak Pro 400 PPF film, composite of two 50-minute exposures)



Hale-Bopp over Mangroves
JOHN MORAN
(35mm lens at f/2, Fujicolor 800 film, 3-minute exposure taken March 27, 1997)

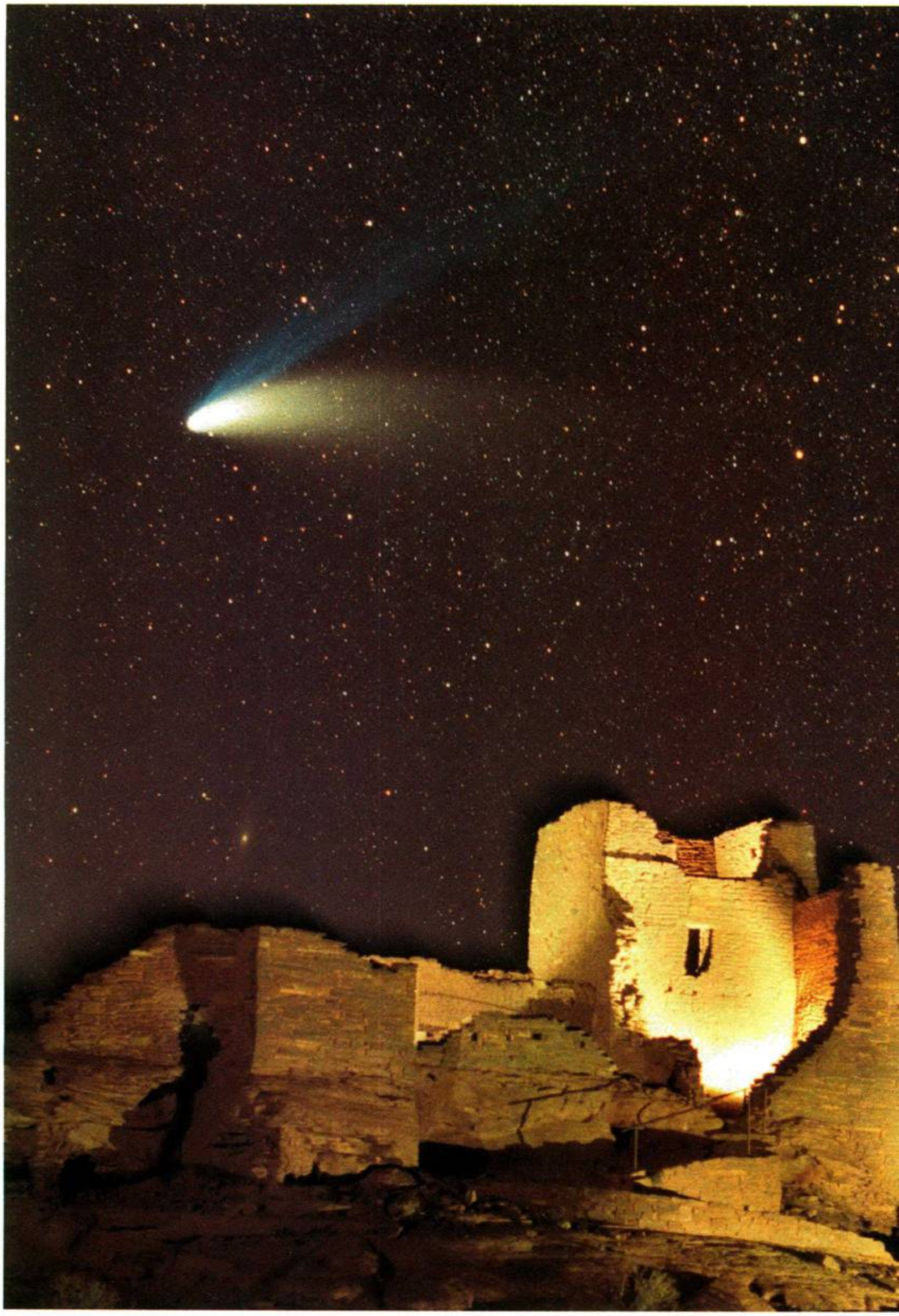
the dust tail. Light-pollution from the nearby city never let me see Hyakutake's tail at all, and made 1986's Halley a binocular object even at its brightest. Even through a horizon fringed with city glow, most of Hale-Bopp's tail filled the field at 40x. At 92x background stars appeared close to the coma, although none shone through the tail itself.

As intriguing as the comet was the Iowa landscape it hung over. The terrain here is what we Iowans call "Kansas flat." There were no boom boxes, no noisy cars. Suddenly a cow bawled in the distance. But after a while, once again total silence descended under the stars. Hale-Bopp literally dangled over its foreground, a sweeping form that barely hinted of an incredible volatility that made a 25-mile-wide snowball visible from 120 million miles away.

Unfortunately my next clear night was Easter Sunday — unfortunate in that it was a long way from March 11 and very unfortunate because it was also much colder. Still, the Hale-Bopp show was even better, with a tail that stretched to almost the same length of the Big Dipper.

It turns out that abbreviated night would be my last dark-sky view of the comet. Shortly thereafter, a huge staph infection blasted its way through my right knee to eventually threaten my entire right leg. Working around an IV tether, I doggedly lugged a scope out of my basement for a carport view of the comet to the right of the Pleiades.

Even through the lights of suburbia, the comet was a terrific sight, as distinct and



Hale-Bopp and the Andromeda Galaxy (M31) over Prehistoric Ruins in Arizona

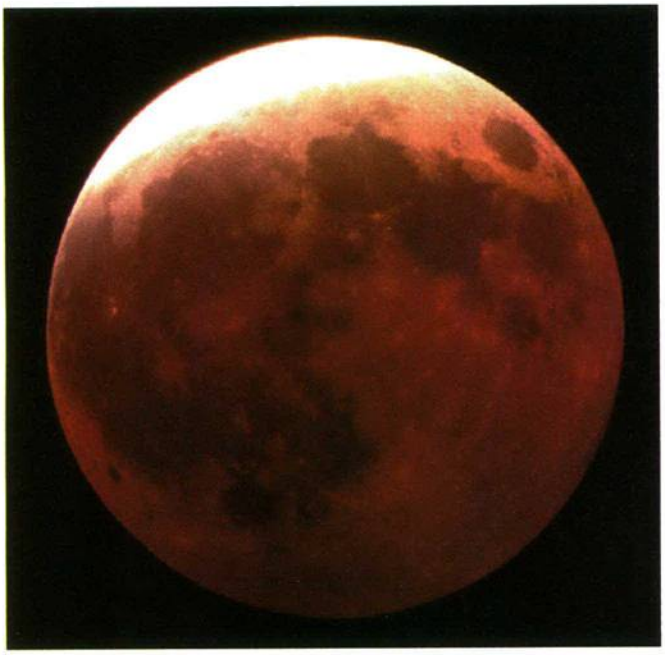
JOSHUA VAUGHAN

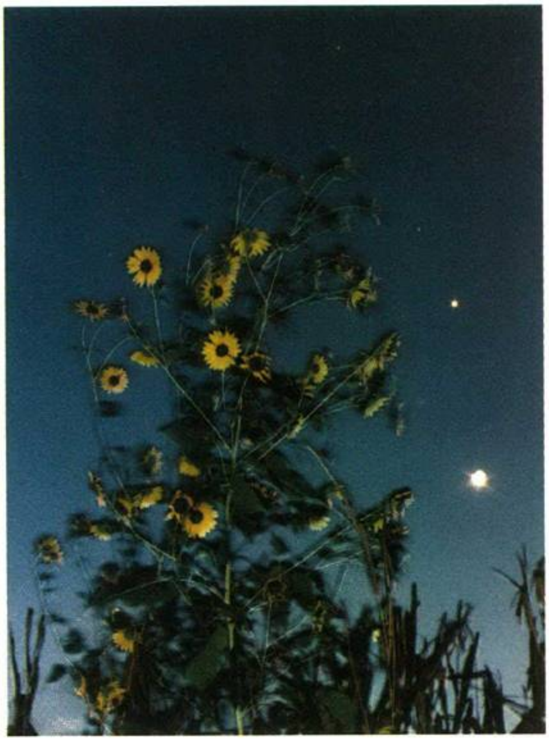
(50mm lens at f/2.8, Fujicolor 800 film, 6-minute exposure taken March 29, 1997 with ruins illuminated by photoflash)

Partial Lunar Eclipse

BRUCE CURRY

(8-inch f/6.3 Schmidt-Cassegrain reflector, Kodak Ektachrome Elite II 100 film, 3-second exposure taken March 23, 1997)

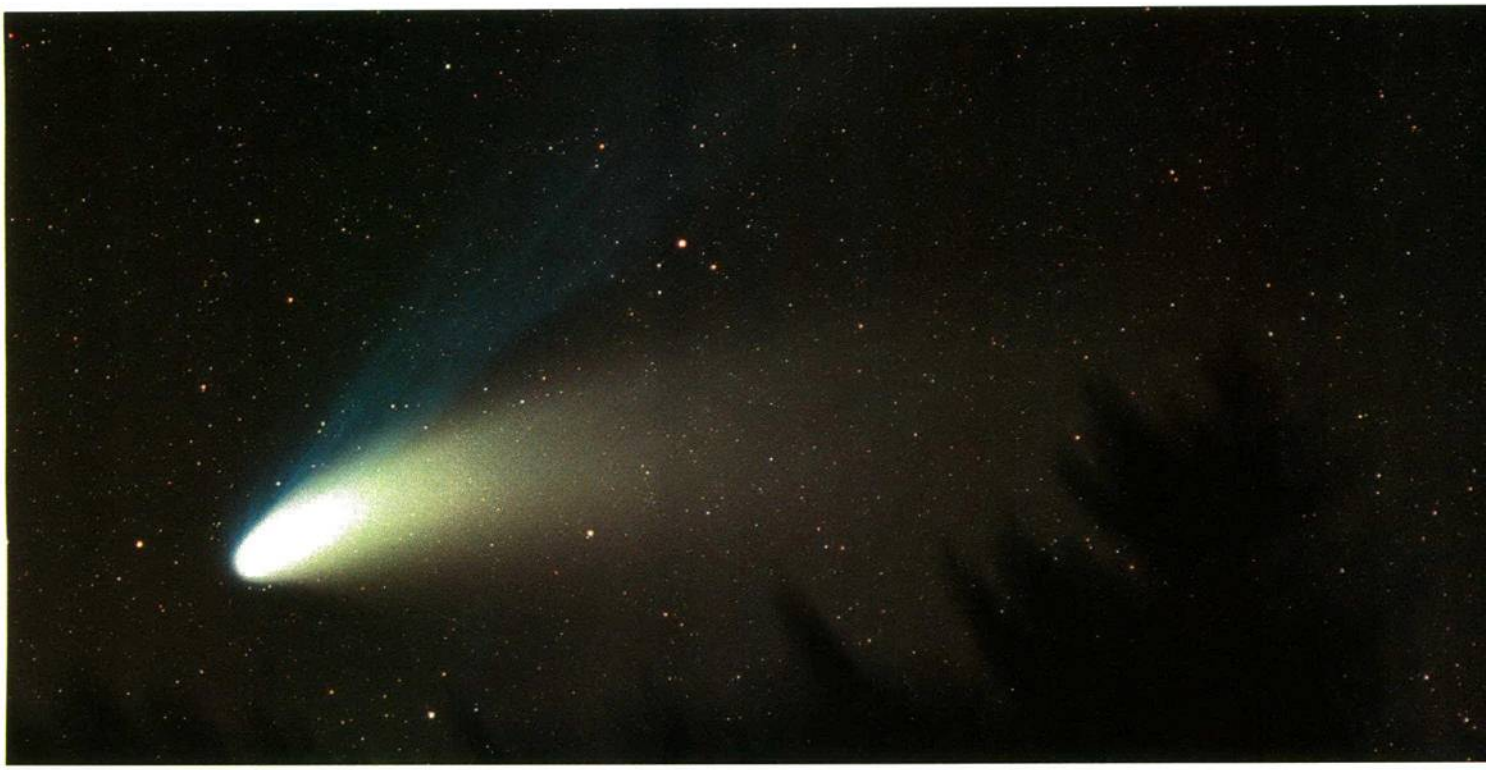




Sunflower Conjunction between the Moon, Venus, Mars, Pollux, and Castor

DOUGLAS C. ZUBENEL

(50mm lens at f/4, Fuji Super G 800 Plus film, 10-second exposure with flash on foreground)



Hale-Bopp Heads for the Trees

GUY-EMMANUEL COLLOMB

(180mm lens f/2.8, Fujicolor 800 film, 4-minute exposure taken March 30, 1997) white as on any other night. "What are those rings I see around the nucleus?" my wife asked. I assured her they were just an optical illusion caused by diffraction and a badly-collimated mirror. Several days later, I realized we had seen great spiraling whips of matter swirling hundreds of thousands of miles from the comet body itself. Not bad for light-polluted skies.

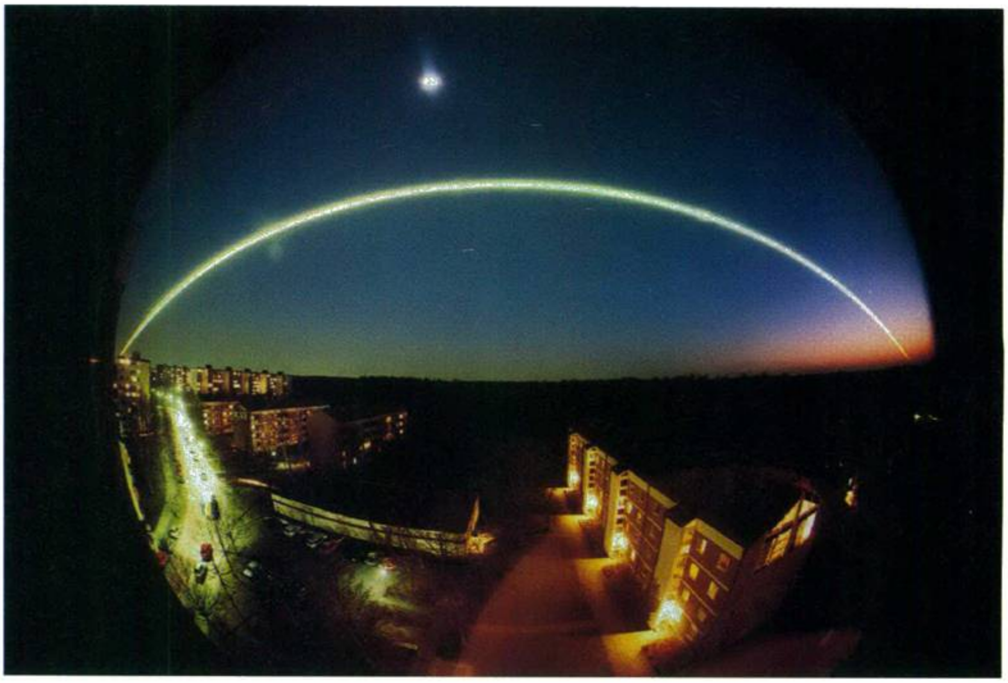
I remained homebound through April. But even from my backyard, I could monitor Hale Bopp's glorious tail and make approximate measurements of its pseudo-nucleus. By sweeping back and forth between Mars and the comet with the same eyepiece, and knowing the distance of both objects, I deduced the pseudo-nucleus to be a little bigger than Earth, perhaps 10,000 miles in diameter.

On April 25 I lugged my 10-inch Dobsonian out of the basement for a last look at the departing comet. As an antibiotic pump whirred away to preserve whatever upper hand my frail body held over a lingering infection, I bundled up and communed again with a distant celestial friend. One of us will be back in two thousand years. I don't have to guess too hard to figure out who it will be.

—John R. Turner

Turner (IABardman@aol.com) is an English teacher in Davenport, Iowa, and an amateur astronomer.

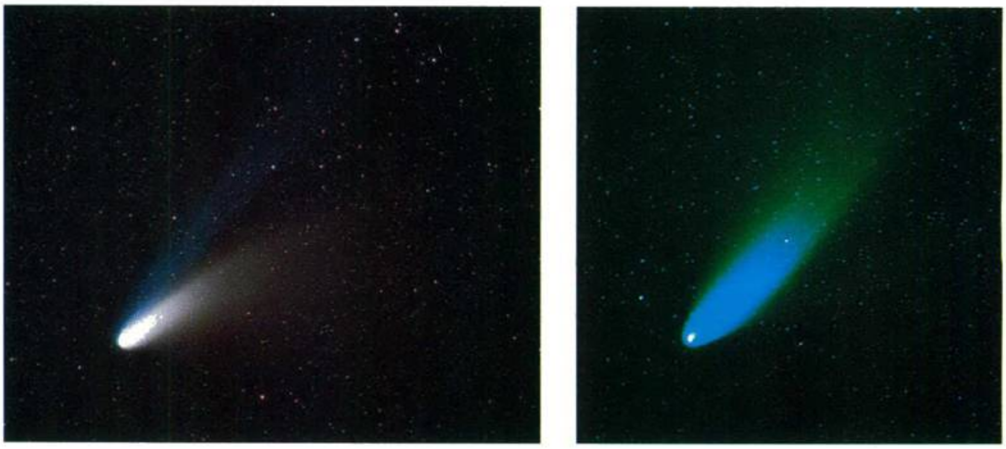
Send reports, stories, sketches, photographs, and disks to Hot Shots Editor, Astronomy, *P.O. Box 1612, Waukesha, WI 53187-1612. Send written reports and images via the Internet to: hotshots@astronomy.com.*



Twenty-Four Hours over Munich, March 11, 1995

KARL BRANDL

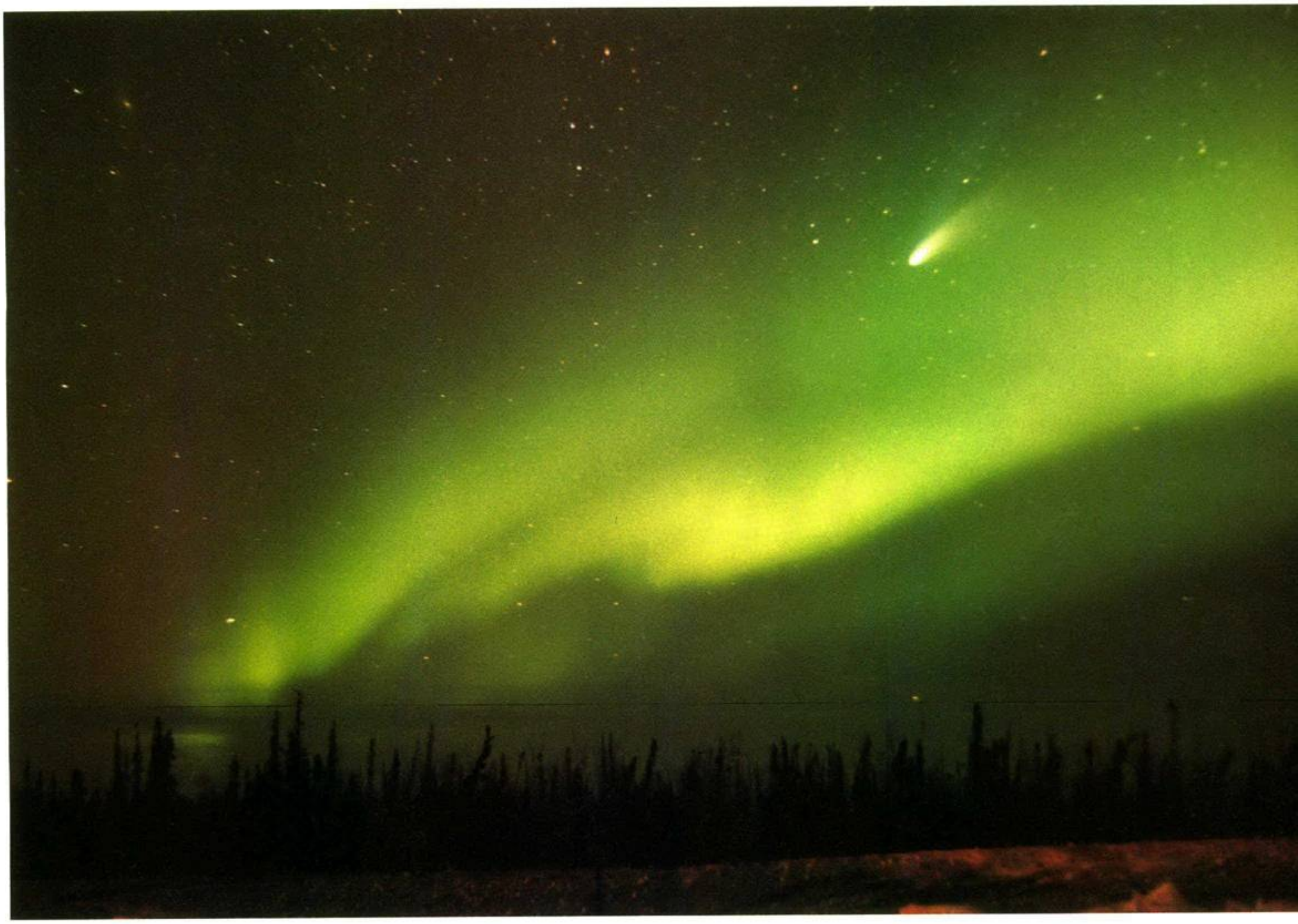
(30mm lens, 4x5 camera, Fujichrome Velvia 50 film, 11½-hour daytime exposure at f/22 through a grade-6 neutral density filter, followed by an 8-minute exposure at f/5.6)

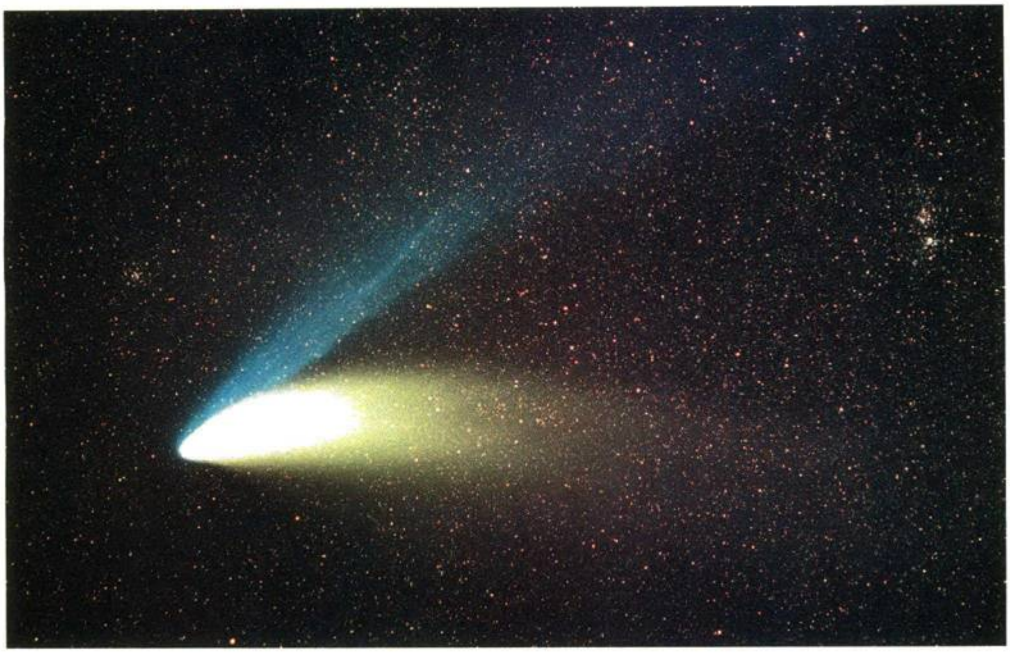


The Comet in Visual and Infrared Light

DALE O'DELL AND JOSHUA VAUGHAN

An exposure taken on Kodak Elite 400 film through a 135mm f/2.8 lens for eight minutes (left) captures Hale-Bopp's white dust tail and blue ion tail. Only the comet's dust tail, which gives off warmth absorbed by the sun, stands out in the infrared view (right) taken on Kodak Professional EIR #2236 film through a 200mm f/4 lens for 12 minutes. Both pictures were shot March 12, 1997.





Hale-Bopp Shines through an Alaskan Aurora

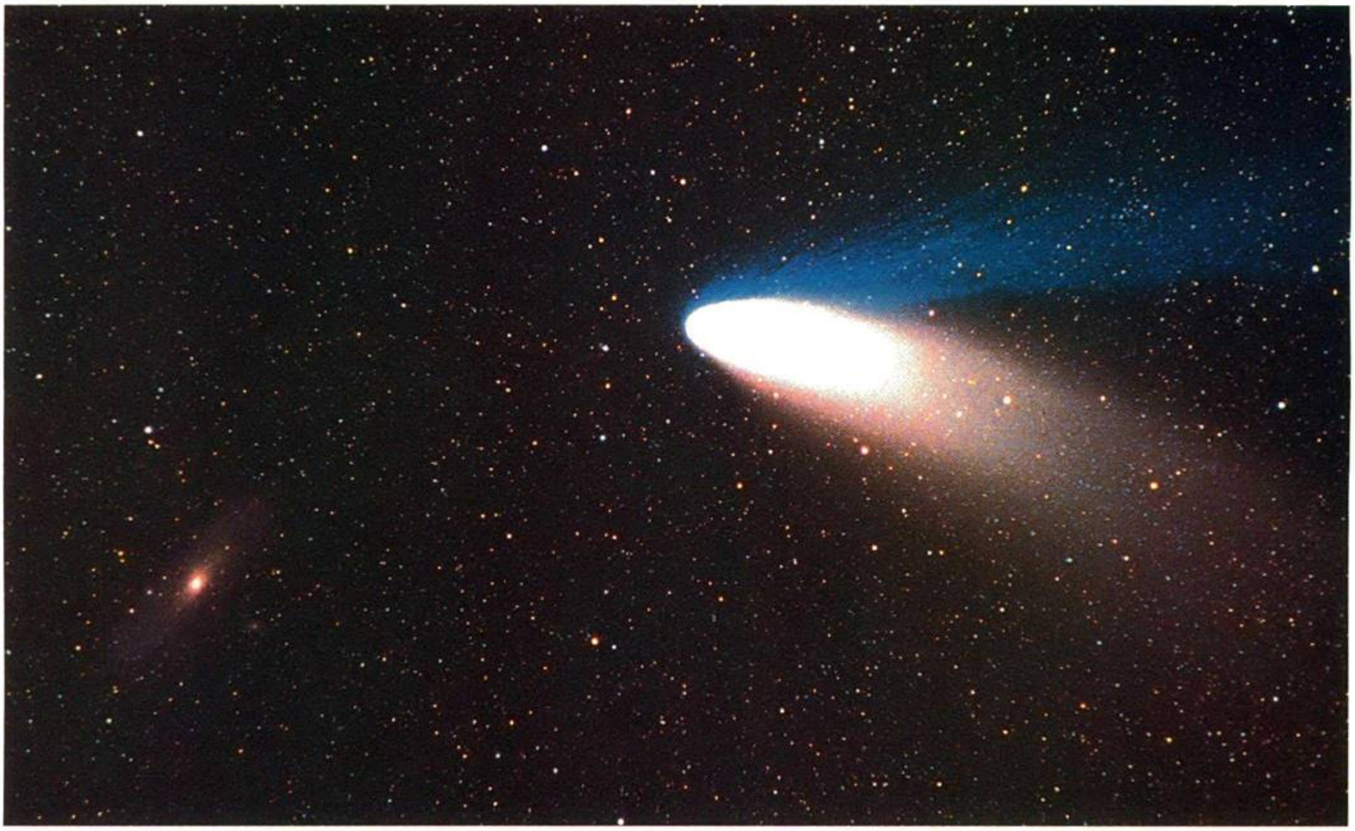
DAVID CARTIER

(35mm lens at f/2.8, Fujicolor 800 film, 24-second exposure taken March 12, 1997)

Hale-Bopp with Star Cluster M34 and the Double Cluster in Perseus

LOKE KUN TAN

(165mm lens at f/2.8, medium format camera, hypered Kodak Pro 400 PPF film, two 8-minute exposures taken April 4, 1997)



Hale-Bopp Encounters the Andromeda Galaxy (M31)

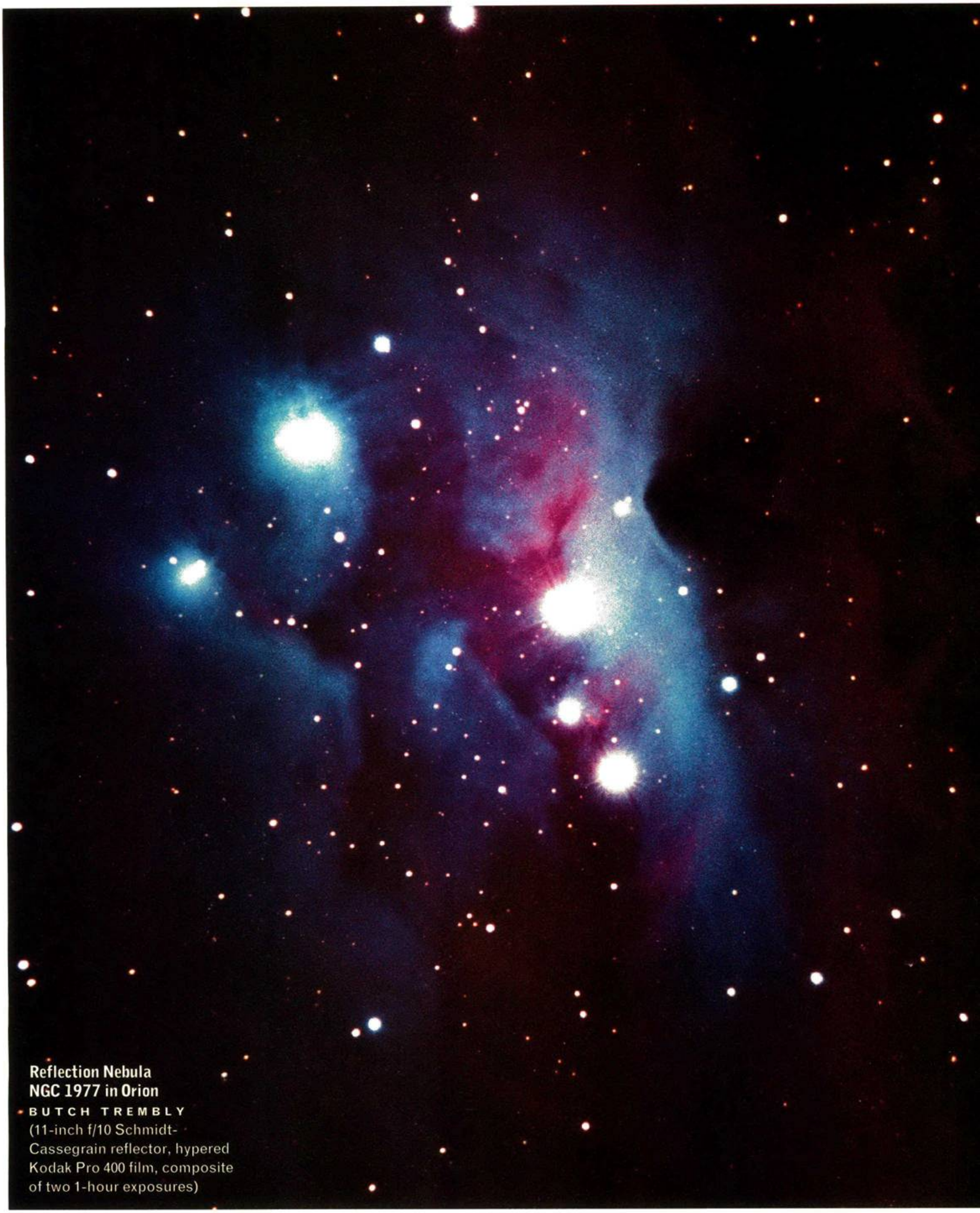
JAMES FOSTER

(135mm lens at f/4, Fujichrome G800 film, composite of 8- and 10-minute exposures taken March 26, 1997)

The Comet in Twilight Clouds

KIERSTIN ALLEN SMITH

(28mm lens at f/4.5, Fujicolor Super HG 400 film, 30-second exposure)

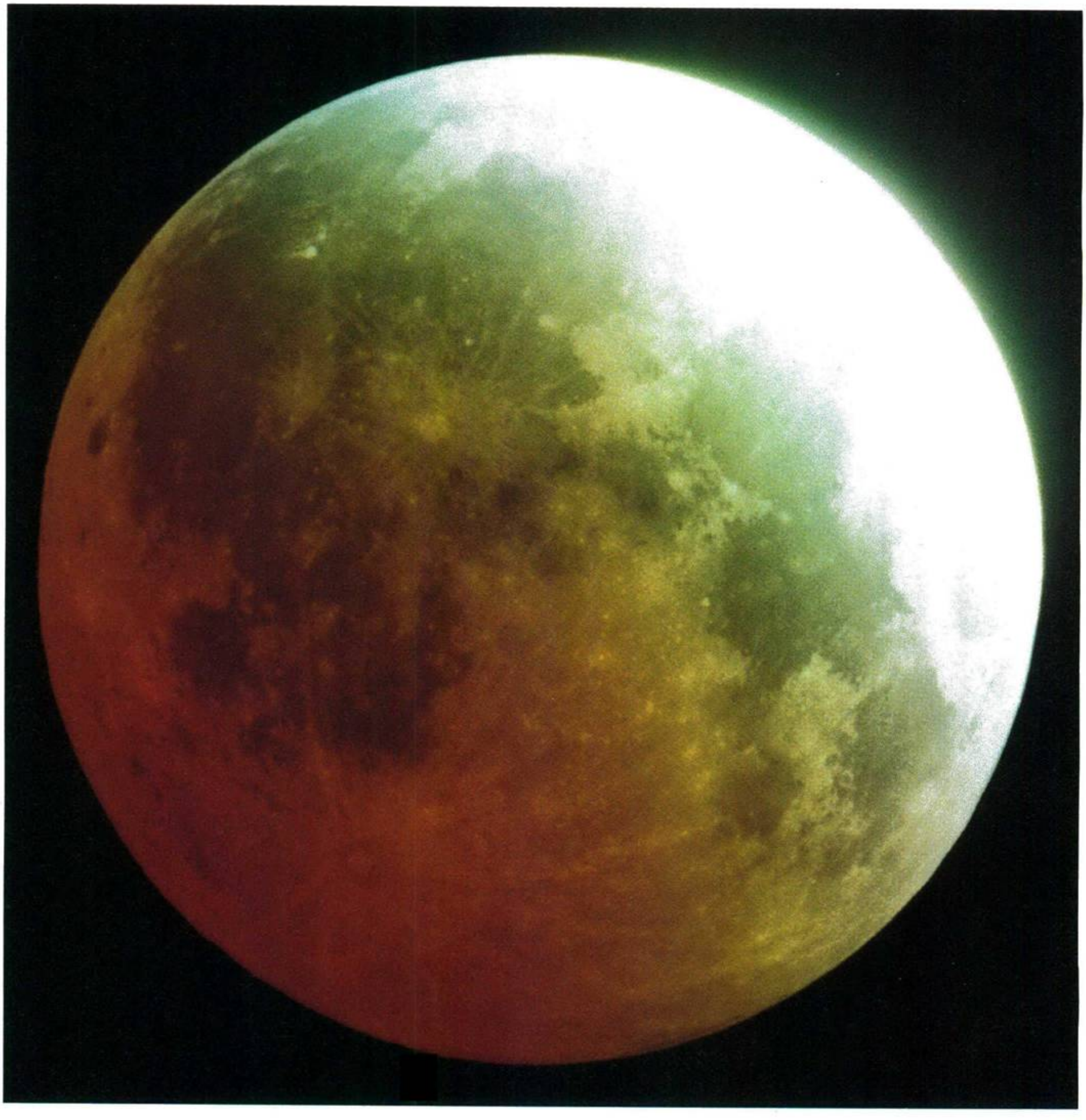


Reflection Nebula NGC 1977 in Orion

BUTCH TREMBLY

(11-inch f/10 Schmidt-Cassegrain reflector, hypered Kodak Pro 400 film, composite of two 1-hour exposures)

This month's best astrophoto



A Vernal Lunar Eclipse, March 23, 1997

GREGORY TERRANCE

(10-inch f/7 reflector, Fuji Super 800 Plus film, 5-second exposure)

Last March's 92%-eclipsed moon added still more spectacle to a spring night already energized by Comet Hale-Bopp. Initial reports from observers mention that this eclipse was particularly colorful, with the usual reds and oranges offset by softer tones of magenta and green. The colorplay was due to sunlight *shining through* Earth's atmosphere onto the moon's face. Terrance recorded the lunar light show from his observatory in upstate New York.

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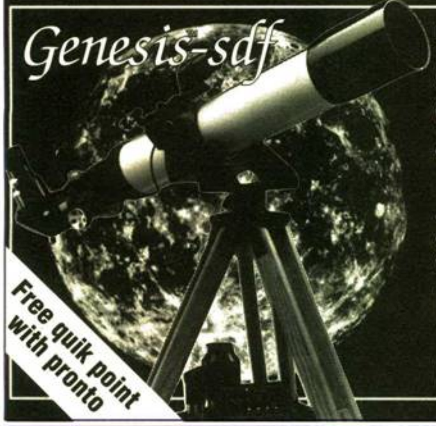

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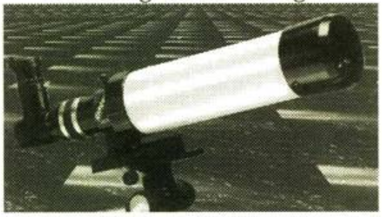

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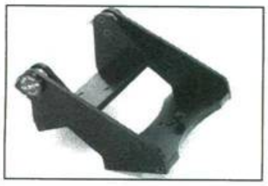
How to Swing on a Star



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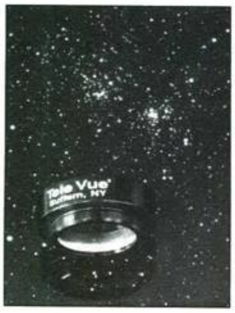

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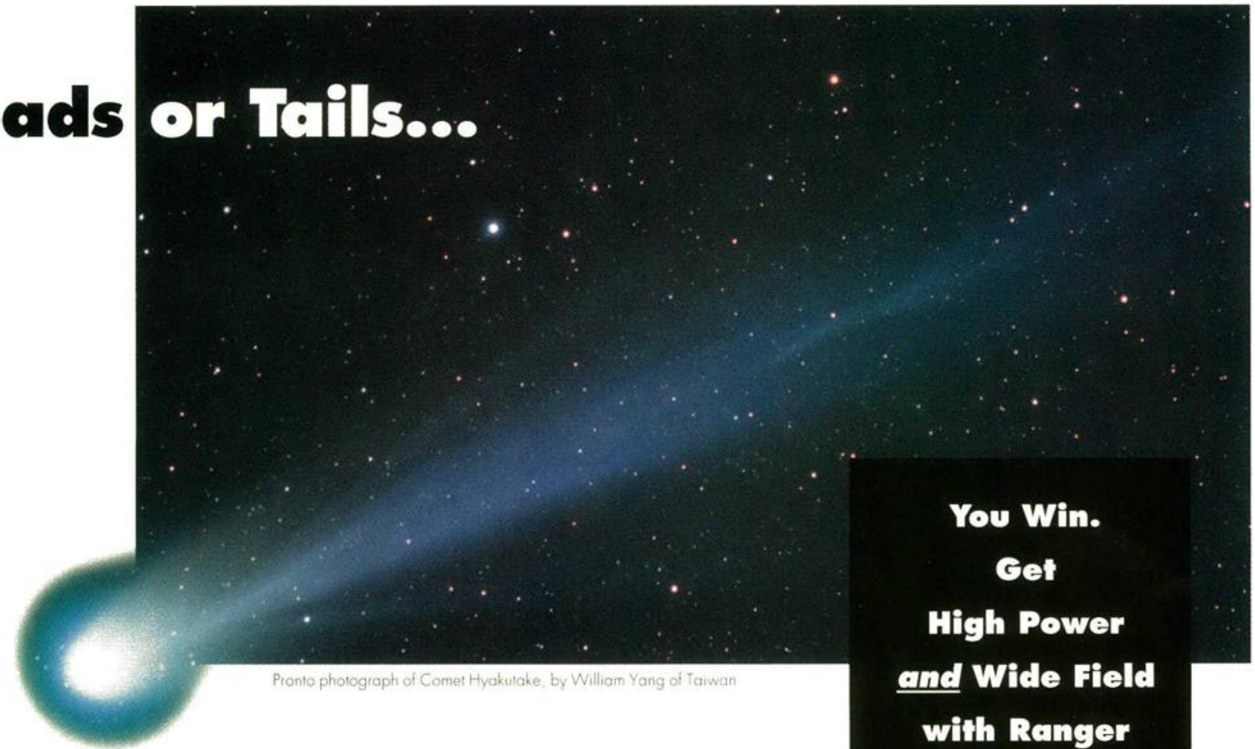


Pronto photograph of Comet Hyakutake, by William Yang of Taiwan

**You Win.
Get
High Power
and Wide Field
with Ranger
& Pronto.**

Ranger

	Ranger	Pronto
Objective:	2-element, E.D.	Same
Power Range:	12x - over 200x	9x - over 200x
Visual Field:	3.3°	5.5°
Photo Field:	5.2° 35mm film diag.	Same
Aperture:	70mm	Same
Focal Length:	480mm	Same
Focal Ratio:	f/6.8	Same
Focus Type:	1¼", 2 Stage with Helical	2" Rack & Pinion
Dew Shield:	Available	Captive, Sliding
Mounting:	¼-20 Balance Bar	¼-20 Mount Ring
Carry Bag:	Available	Custom Padded
Choices:	1¼" Mirror Diag., 1¼" 45°, or Porro Prisms	2" or 1¼" Mirror Diags., 1¼" 45°, or Porro Prisms
Accessories:	All 1¼" Tele Vue eyepieces 2x Barlow optimum All Tele Vue Mounts Qwik-Point 35mm Camera Adapter Padded Shoulder Bag Padded Fitted Bag Rubber Lens Shade	All Tele Vue eyepieces All Tele Vue Barlows All Tele Vue Mounts Starbeam or Qwik-Point 35mm Camera Adapter Piggy-Cam

- *I wanted an extremely portable instrument of superb quality. I consider Pronto to be the Questar of refractors. It is of superb manufacture and the views are razor sharp with beautiful contrast. — J.B. AZ*
- *I really like the RFT/diffraction limited design. And, Pronto was within budget. I'm very pleased! Not only could I see Io's shadow clearly transit Jupiter (at 95x), but I could trace Io itself across the planet's darker limb - even in front of a lighter band of clouds. Thanks again. — B.O. IL*
- *I'm impressed. Ranger performs like a larger aperture telescope. A star test revealed perfect diffraction patterns. — A.G. TX*
- *Great optics, great machining. Spectacular low-power views; seems much larger than 70mm; lots of detail on high power Jupiter. — P.R. NY*
- *I needed a grab and go scope with guts. Ranger is an astounding instrument! My 8" can't keep up with this rascal — N.R. NE*
- *I need portability; to carry on flights - (airline crew). Pronto is a beautiful scope; my first look at Jupiter and Saturn convinced me I had made the right choice. Thank You. — P.H. Hong Kong*

Pronto

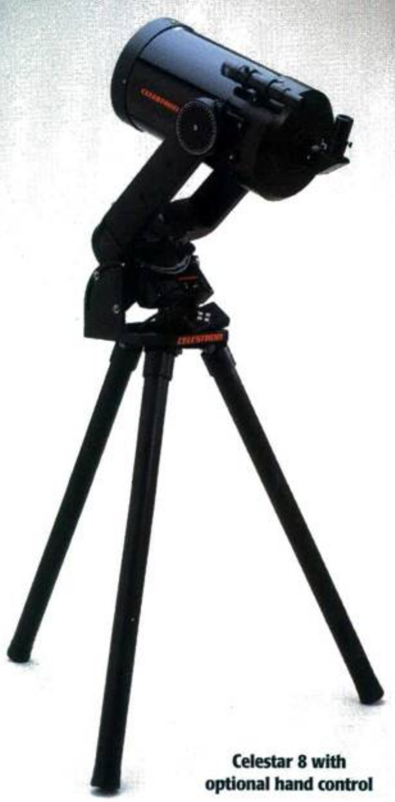
*Product flyer free or send $3 for full-line literature.
Visit the Tele Vue web site at http://www.televue.com
Tele Vue Optics, Dept. A, 100 Route 59, Suffern, NY 10901. (914) 357-9522.*

Tele Vue®

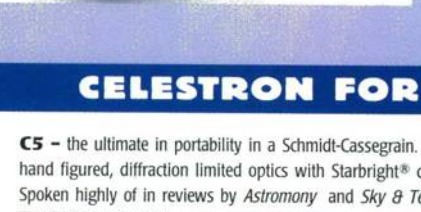
CELESTAR 8 *by* Celestron®

THE LOWEST PRICE EVER ON AN 8" CELESTRON FORK-MOUNTED SCHMIDT-CASSEGRAIN TELESCOPE

- An economical but full featured 8" Schmidt-Cassegrain. A considerable amount of engineering work went into the design of the Celestar 8 to offer the lowest price **ever** on a **Celestron** fork mounted 8" with so many features.
- No sacrifice was made in the optics as the superior quality **Celestron** hand-figured system with Starbright® coatings is standard.
- The electronics are DC and the same as supplied with the C5⁺ telescope.
- The totally cordless electronics have a built-in drive corrector which is activated when using the optional hand control. The R.A. motor's main tracking speed is an accurately regulated sidereal rate. The optional hand control allows fast and slow override of R.A. tracking speed and ± operation of the optional DEC motor. A comment from the *Sky & Telescope* review – "the digital electronics of the C5⁺ delivered a near-perfect sidereal tracking rate."
- The Celestar 8 is powered by a single 9-volt alkaline battery and runs for 50 hours! The Celestar 8 drive can operate in the Northern or Southern hemisphere from 0 to 90°.
- The new and unique Wedgpod is a combination tripod and wedge. It has a fixed height (33") and is lightweight without compromising its stability.
- **Made in the U.S.A.**
- Standard accessories included are: 6x30 Finderscope, Star Diagonal – 1¼" and a 25mm SMA Eyepiece – 1¼" (81x).



Celestar 8 with optional hand control



The **Celestar 8 Computerized** telescope is the same as the Celestar 8 but with the addition of a factory **installed** and **tested** Advanced Astro Master®.

This pointing system contains a data base of over 10,000 objects. Once aligned, it will guide you to any one of these objects. Included are the entire RNGC catalog, the Messier catalog, IC catalog (selected objects), major planets, over 241 interesting double and multiple stars and a user definable catalog of 25 objects. Operates on a standard 9V battery.

Contains an RS-232 serial interface to enable usage from PC programs.

CELESTRON FORK MOUNTED SCHMIDT-CASSEGRAIN TELESCOPES

C5 – the ultimate in portability in a Schmidt-Cassegrain. 5" f/10 hand figured, diffraction limited optics with Starbright® coatings. Spoken highly of in reviews by *Astromony* and *Sky & Telescope*. The C5 is an AC model. The **C5⁺** is a DC model for astronomy on the go and it runs off a single 9-volt alkaline battery. The C5⁺ also comes with a built-in drive controller. Included standard are the equatorial wedge, 5 x 24 Finderscope, Star Diagonal – 1¼ and a 25mm SMA eyepiece – 1¼".

ULTIMA® 9¼ – 2350mm f/10 with Starbright® coatings. A new, large aperture size utilizing the renowned Ultima PEC drive – totally cordless DC servo quartz drive system with PEC and powered by a single 9-volt alkaline battery. A unique focusing micrometer for ultra precise focusing for CCD imaging or astrophotography is included. Standard accessories are wedge, tripod, 6x30 Finderscope, hand control, 25mm SMA eyepiece – 1¼".

ULTIMA® 11 – 2800mm f/10 with Starbright® coatings. The largest Ultima (11") has been redesigned with more rigid sand castings for additional stability. Utilizes the same drive base as the Ultima 9¼ of which *Sky & Telescope* said, "Ultima's drive error was the least I have ever seen in a mass-market telescope". Standard accessories include a wedge, tripod, 7x50 Finderscope, hand control, 26mm Plössl eyepiece – 1¼".

CELESTRON®

For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

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